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REVIEW AND RECOMMENDATIONS ON A LEAD IN SOIL GUIDELINE

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REPORT TO THE MINISTER OF THE ENVIRONMENT
BY THE LEAD IN SOIL COMMITTEE

Ontario

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Report to the Minister of the Environment
by the Lead in Soil Committee

Prepared by the Hazardous Contaminants Branch

May 1987

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1.0 CHAIRMAN'S SUMMARY

Background

- At the Minister of the Environment's request, a Committee of technical staff of a number of federal, provincial and municipal government agencies and representatives of community public interest groups and the lead industry, was convened to provide scientific advice on an acceptable level of lead in soil in conjunction with an announced soil removal program in the South Riverdale area of Toronto. Ministry of the Environment staff filled the positions of Chairman and Executive Secretary (Refer to Appendix 12.2 for List of Committee members).

- The Committee was asked to provide its advice on the basis of available scientific information within four months of its inaugural meeting (Refer to Appendices 12.3 and 12.4 for Terms of Reference and Work Plan).

- The Chairman wishes to commend the members of the Committee for their commitment to the task; their willingness to listen to other Committee members; and the clarity of their opinions on the complex issue of environmental exposure to lead. Many of the Committee members have worked on various aspects of the lead issue for several years and have a wealth of knowledge on the topic of lead contaminated soil. The Chairman and Executive Secretary came to the task without the benefit of such historical experience on the lead issue. We wish to thank the Committee members for sharing their expertise.

- The report which follows summarizes the technical and scientific information evaluated by the Committee; describes the discussions, conclusions and recommendations reached; identifies the areas where disagreement among Committee members existed and, where possible, the rationale for the varying opinions. The drafts and final report were prepared by the Executive Secretary and Chairman. Committee members reviewed all drafts through a series of four meetings, and their final written comments have been incorporated to the greatest extent possible. Members were invited to submit any dissenting opinions for inclusion as appendices to this Report (Refer to Appendix 12.6).

- Several groups indicated, at the outset, their intention to make separate submissions to the Minister in support of their positions on the issue of the Minister's announced soil replacement program. A number of such submissions are expected.

Major Findings

- Lead is an environmental contaminant with a wide variety of well-documented adverse human health effects. Health experts, over time, have been revising downward their estimates as to what level of lead in blood constitutes a health hazard. There is continuing debate about the significance of blood lead levels found in children (Refer to Section 3.0 for description of Toxicology).

- Lead is present in many environmental media such as air, water and soil, and is, therefore, a multi-media contaminant. It originates from a number of sources (e.g., exhaust from automobiles, point sources such as lead smelters, leaded water service connections, lead solder, and lead in paint). Humans are exposed to lead through both ingestion and inhalation (Refer to Section 4.0).

- Lead moves from one medium to another, making it difficult to assess the relative contribution of various sources to an individual's exposure. This, in turn, makes decisions on the effectiveness of single control measures difficult. Empirical scientific information, which would aid in evaluating the environmental sources and fate of lead and the contribution of various media to human exposure, is lacking in a number of key areas (Refer to Section 5.0).

- In the absence of definitive information, the Committee members held divergent opinions as to what is an appropriate guideline level for lead in soil (Refer to Section 7.0).

Conclusions

1. It is prudent to lower children's blood lead levels as much as practically possible.

2. While available evidence is insufficient in a number of areas, the available evidence is sufficient to allow the Committee to provide advice on a reasonable approach for establishing site-specific soil lead guideline levels.

3. The elevated blood lead levels observed in children under the age of six in the vicinity of the secondary lead smelter in South Riverdale are of sufficient concern to warrant remedial environmental action.

4. The observed difference in blood lead levels between the South Riverdale children and the urban "control" children is probably due to environmental lead sources. These environmental sources include air and dustfall lead, soil lead and house dust lead.

5. Children's blood lead levels appear to vary directly with soil lead levels. However, although soil lead levels may be predictive of blood lead levels in a particular community, this cannot be extrapolated to mean that removal of soil lead will necessarily result in a significant reduction in blood lead levels.

6. The reduction of air and dustfall lead levels, soil lead levels and house dust lead levels to urban "background" levels would be likely to result in a lowering of the blood lead levels in children in South Riverdale to urban "background" levels.

7. Soil lead/blood lead relationships are site-specific due to the influence of many variables, such as socio-economic and environmental factors, and insufficient evidence exists for the accurate determination of this relationship in Ontario.

8. The probable environmental lead pathway, influencing blood lead levels in children in South Riverdale, involves air and dustfall lead, soil lead, and house dust lead. Available evidence is insufficient to conclude whether or not blood lead levels would be lowered significantly by remedial action against any one of these lead sources alone.

9. Soil lead removal alone, without thorough lead-contaminated house dust removal, is unlikely to result in a major decrease in mean blood lead levels.

10. Soil lead and house dust lead removal may not result in a significant long-term reduction in blood lead levels unless the air and dustfall lead levels are reduced to appropriate levels.

11. Available evidence indicates that the availability of soil lead, primarily through dust formation, is a critical factor in determining the influence of soil lead on blood lead through the soil lead ⟶ house dust lead ⟶ blood lead pathway. Soil lead that is always covered by sufficient grass appears to be bound and less influential on blood lead.

12. The lack of statistical correlation between the blood lead levels of individual children and their residential soil lead levels, and the available evidence indicating that environmental lead throughout a community plays a role in elevating blood lead levels, indicate that remedial measures should be applied to the community as a whole, not just to residential property.

13. Remedial dust control measures should be undertaken on non-residential lead-contaminated soil that is not directly accessible to children to prevent re-entrainment of the dust lead in the community. Remedial measures may simply involve sodding of open dirt areas, or could involve paving or soil replacement.

14. Based on the World Health Organization's recommended maximum tolerable daily intake for young children, and on current estimates of dust ingestion in young children, the highest dust lead level that would keep the average young child within the maximum tolerable daily lead intake (assuming 50% of the ... maximum tolerable daily intake comes from soil/dust) is 500 ppm. However, this must be interpreted cautiously.

15. The proposed 500 ppm soil lead guideline for growing root and leafy vegetables is appropriate, based on current information. This guideline level cannot be extrapolated to provide a basis for the contribution of soil lead levels, to blood lead levels, through the soil lead ⟶ dust lead ⟶ blood lead pathway.

16. Current information on environmental lead/blood lead interactions in Ontario is lacking. If a thorough epidemiological study was to be conducted at the time that the remedial action was undertaken, the information gathered would be valuable to the review of environmental lead guidelines and standards in the future.

Recommendations

It is recommended that:

1. Soil lead guideline levels be established between 500 ppm and 1000 ppm.

   A 500 ppm guideline level is appropriate for agricultural areas.

   A 1000 ppm guideline level is appropriate for areas to which children do not have routine access.

   A guideline level between 500 and 1000 ppm is appropriate for areas to which children do have routine access. Socio-economic and technical factors should be assessed in determining the actual guideline levels for specific sites.

   The Committee representatives from government and industry are of the opinion that available scientific evidence does not support a soil lead guideline level lower than 1000 ppm. However, for sites to which children do have routine access, the representatives from the South Riverdale Community Health Centre, the Niagara Neighbourhood Association, the Ontario Association for Children and Adults with Learning Disabilities and the

Toronto Department of Public Health feel that a 500 ppm guideline level is necessary;

2. Soil removal, where conducted, should occur to a depth of 30 cm.

   Excavated soil should be subjected to the leachate extraction procedure set out in Regulation 309 under the Ontario Environmental Protection Act to determine whether or not it is a hazardous waste. If it is not a hazardous waste, it can be deposited in an approved landfill site. If it is a hazardous waste, then special disposal arrangements will be necessary;

3. Soil removal should be accompanied by thorough dust removal from the community in order to maximize the potential for blood lead reduction. This would involve cleaning the interior of houses and also dusty commercial and industrial areas (e.g., parking lots) in order to avoid re-entrainment of lead-contaminated dust.

   Ideally, soil and dust removal should be accompanied by action to lower air lead and dustfall lead levels so that long-term blood lead reduction may be realized;

4. Protocols for soil removal and dust removal should be established and assessed prior to the initiation of remedial action;

5. A rigorous epidemiological survey should be conducted in conjunction with the clean-up efforts. Protocols for such a study should be thoroughly assessed and evaluated prior to its initiation.

   The information gained from such a study will be valuable for future reviews of environmental lead standards and guidelines;

6. The Ministry of the Environment undertake a review of all environmental lead standards, guidelines and criteria in the light of recent medical evidence on the potentially adverse affects of lead at very low blood lead levels.

   In addition, it is recommended that a dustfall standard for lead be established, if feasible; and

7. Although the Royal Society of Canada Lead Report recommends that soil replacement be undertaken only where blood lead surveys indicate that the geometric mean blood lead level of the children studied is significantly elevated (i.e. $\geq$ 3 ug/dl) above background, the Committee recommends that in communities such as the Niagara Neighbourhood where too few children may reside to allow a statistically significant blood lead survey, remedial action should be taken if the soil lead levels exceed the guideline level.

2.0 INTRODUCTION

2.1 Background

In December 1986, the Ontario Ministry of the Environment established the Lead in Soil Committee to recommend a "scientifically defensible" soil removal guideline (see pg.42) for lead-contaminated soil. The Committee was comprised of representatives from the Ontario Ministries of Environment, Health, and Labour; Health & Welfare Canada, City of Toronto Department of Public Health, concerned citizen groups, and the lead industry. Details of the committee membership are provided in Appendix 12.2.

This report presents the conclusions and recommendations of the Committee, as well as a summary of the relevant scientific information.

2.2 Historical Perspective

In 1974, in response to public health concerns regarding the contribution of lead in soil to elevated blood lead levels in children, the Environmental Hearing Board held public meetings on lead contamination in th Metropolitan Toronto area.

Based on the findings and recommendations of the Environmental Hearing Board, the Ontario Ministry of the Environment established a replacement guideline for lead contaminated soil of 2600 ppm, and removed lead-contaminated soil from 58 properties in Toronto in 1977.

Regulatory agencies, in light of scientific evidence available at that time, indicated that blood lead levels up to 40 ug/dl posed no significant adverse human health effects. However, medical evidence gathered over the past decade has resulted in a re-evaluation of the potential health hazards of blood lead levels "previously thought to be safe" (CDC, 1985). Based upon this recent evidence, the Toronto Department of Public Health has established 20 ug/dl blood lead as an intervention level requiring further investigation.

Blood lead surveys conducted in Ontario have indicated that some children have blood lead levels approaching or exceeding the 20 ug/dl intervention level. In particular, blood lead surveys conducted by the Toronto Department of Public Health in the South Riverdale area of Toronto, have shown that a higher proportion of children under the age of 6 in that area have blood lead levels exceeding the 20 ug/dl intervention level. Eighteen percent of the South Riverdale children, as compared with 5.1% of urban children evaluated in the Ontario Blood Lead Study, had blood lead levels in excess of 20 ug/dl.

These studies, and many others, indicate that lead contaminated soil may be associated with elevated children's blood lead levels. In both the South Riverdale and Ontario blood lead studies, soil lead levels were found to be significantly correlated with elevated blood lead levels. The Toronto City Council and the Royal Society of Canada's Commission on Lead in the Environment have recommended that soil containing 500 ppm or more of lead be removed from contaminated properties as part of a remedial program in lead contaminated areas.

In November 1986, the Ontario Minister of the Environment announced that the removal of lead contaminated soil in South Riverdale would commence in 1987, and the Lead in Soil Committee was formed in December 1986, to recommend a scientifically defensible soil removal guideline.

2.3 Approach

The Terms of Reference and Work Plan for the task were agreed upon (see Appendices 12.3 and 12.4) at the inaugural meeting of the Lead in Soil Committee in January, 1987.

The Committee established that, in order to assess the contribution of soil lead to elevated blood lead levels, it would be necessary to assess the relative contribution of other sources of lead that contribute to blood lead levels. Consequently, the approach taken by the Committee in preparation of this report was as follows:

(a) Review the scientific literature pertaining to the toxicology of lead; the significance of blood lead levels; and the major routes of exposure.

(b) Assess the contribution where possible, of the major sources of blood lead.

(c) Assess the contribution of lead in soil to blood lead levels.

(d) Prepare a report, which summarizes the above, and which presents the rationale for the recommended soil removal guideline.

3.0 TOXICOLOGY OF LEAD

3.1 Intake and Absorption (Uptake) of Lead by Humans

The primary routes of entry of lead into the body are inhalation and ingestion, with ingestion playing the more significant role. Depending upon numerous factors, including age, sex and nutritional status, a percentage of ingested or inhaled lead is excreted while the remainder is absorbed or taken up.

Current estimates indicate that approximately 10-15% of the lead ingested by adults is absorbed through the gastrointestinal tract, while the remainder is excreted. In contrast, several studies estimate that 30-50% of lead ingested by children may be taken up by the body and distributed throughout soft tissue, blood and bone. A child's lead absorption rate may be directly influenced by diet and nutritional status. Deficiencies in calcium, phosphorus and iron have been shown to be correlated with increased blood lead levels, and increased dietary fat intake has been shown to enhance the absorption of lead into the intestine (CDC, 1985).

It has been estimated that adults absorb 30-50% of inhaled lead. Reliable absorption rates for lead inhaled by children have not been established.

3.2 Significance of Blood Lead Levels

Most of the lead absorbed by the human body eventually accumulates in bone, with approximately 95% of the total adult body burden of lead residing in bone. This bone lead is relatively inert in adults and reflects the cumulative exposure to lead throughout one's lifetime.

In children, however, higher mineral turnover in bone means that more lead may be in a labile form and not sequestered, or bound, in the bone. It has been estimated that approximately 75% of a child's body lead may reside in bone.

Blood lead levels, in contrast to bone lead levels, tend to more directly reflect recently absorbed lead and "reflect the dynamic equilibration between absorption, excretion, and deposition in various compartments of the body" (CDC, 1985). Many factors, such as body weight, history of lead exposure, age and sex, contribute to an individual's blood lead level.

Acute lead poisoning, resulting in encephalopathy is usually associated with blood lead levels exceeding 100 ug/dl, although, occasionally, it has been reported at blood lead levels as low as 70 ug/dl (CDC, 1985). Before the mid-1960's, it was felt that a blood lead level below 60 ug/dl was not significantly associated with adverse health effects. This view has now shifted as current data indicate that lead, at levels previously considered "safe", is toxic to developing central nervous systems (CDC, 1985).

Blood lead levels of 10-12 ug/dl or less have been shown to cause measurable effects on the synthesis of haeme, and have been associated with measurable neurobehavioural effects. Haeme biosynthesis refers to the production in the human body of haeme, a precursor to haemoglobin, the oxygen carrying component of the blood. When haeme biosynthesis is affected by the amount of lead in the blood, the level of free erythrocyte protoporphyrin (FEP) in the blood rises. FEP levels increase exponentially above blood lead levels of 15 to 18 ug/dL in children, and above 35 to 40 ug/dL in adults.

In 1985, the Centres for Disease Control in Atlanta lowered its definition of an elevated blood lead level, considered to be a level that reflects excessive absorption of lead, to 25 ug/dl (CDC, 1985). The CDC considers that children with blood lead levels of 25 ug/dl or greater should be considered at risk for the toxic effects of lead and follow-up testing should be conducted. This "intervention level" is not based solely on medical significance, but is also based on practical factors such as the cost-effectiveness of screening procedures and the fact that the established FEP screening procedure is imprecise at blood lead levels below 25 ug/dl. Since FEP may be elevated in several conditions including iron deficiency anaemia, the test has poor specificity to elevated blood lead at blood lead levels below 25 ug/dl.

The United States Environmental Protection Agency indicates that they will recommend that the 25 ug/dl action level be lowered further in light of current information (Grant, 1987).

In Canada, the Toronto Department of Public Health has established 20 ug/dl blood lead as an intervention level requiring attention for children under 6 and women of child-bearing age. Similarly, the Royal Society of Canada's Commission on Lead in the Environment states that "It would be wise to ensure that no child in Canada has a blood lead level above 20 ug"/dl" (RSC, 1986).

Since the above intervention levels were established, a number of additional studies have suggested that additional adverse health effects, particularly in children, may be associated with blood lead levels well below 20 ug/dl.

Schwartz et al. (1986) showed a statistically significant relationship between growth (stature) and childhood blood lead levels. For each 10 ug/dl increase in blood lead from 5 ug/dl to 35 ug/dl, children showed a decrease in height of approximately 1.2 cm.

A recent U.S. EPA report indicates that elevated lead levels may be correlated with hearing loss in some children. This report suggests that blood lead levels as low as 5 ug/dl may be associated with minor hearing problems (Schwartz and Otto, 1986). Although the hearing problems themselves would not warrant corrective measures, the authors point out that any measurable hearing impairments, no matter how minor, can affect learning.

The possible toxic effects of lead on human reproductive functions have been a concern for more than a century. Many early studies concentrated on the toxic effects on women exposed to very high levels of lead. In recent years, attention has been focused on the possible association of prenatal lead exposure and various developmental outcomes in foetuses, infants, or young children. These recent studies have estimated prenatal lead exposure through measurement of maternal or cord blood lead levels.

Needleman et al. (1984), based on a study of the hospital records of 4354 children in Boston, described an association between umbilical cord blood lead levels and certain minor congenital abnormalities. Although a statistically significant association was found between cord blood lead levels and the collective occurrence of minor abnormalities, no significant relationship was found between cord blood lead levels and any individual type of malformation.

A major study of the effects of prenatal lead exposure and child development is currently underway in Australia. McMichael et al. (1986) followed the pregnancies of 774 women, measuring blood lead levels at least three times during each pregnancy and also measuring cord blood lead levels. Results indicate that pre-term delivery, defined as birth before the 37th week of pregnancy, increased greater than four-fold at blood lead levels above 14 ug/dl.

Bellinger et al. (1984), using the Bayley Scales of Infant Development to assess mental and psychomotor development, reported that Bayley Mental Development Index (MDI) scores were inversely related to cord blood lead levels. This study of 216 - 6 month old Boston children, where 90% of the cord blood lead levels were below 16 ug/dl and the highest level was 25 ug/dl, was the first to report this effect on Bayley MDI scores.

Follow-up studies by Bellinger et al. (1986(a); 1986(b); 1987) indicate that this inverse relationship between Bayley MDI scores and cord blood lead levels is still apparent at 2 years of age.

Several studies assessing the relationship between blood lead levels and intelligence quotient (IQ) have been reviewed by the U.S. Environmental Protection Agency (EPA, 1986). The EPA evaluation indicates that there is evidence of approximately a 5 point decrement in IQ associated with blood lead levels of 50-70 ug/dl, that IQ decrements of about 4 points are observed with blood lead levels of 30-50 ug/dl, and that at blood lead levels between 15 and 30 ug/dl, the evidence is mixed but suggestive of an IQ decrement of 1-2 points.

The EPA concludes that none of the available studies, considered alone, proves that significant cognitive (IQ) or behavioural effects occur in children at blood lead levels lower than 30 ug/dl. However, "the most recent neuro-behavioural studies of CNS cognitive (IQ) effects collectively demonstrate associations between neuropsychologic deficits and ... blood lead levels ranging to below 30 ug/dl" (EPA, 1986).

The findings of these and other studies on the effects of prenatal blood lead exposure on foetal and child development, have been reviewed by the U.S. EPA (EPA, 1986). They conclude that "All of these studies taken together suggest that neuro-behavioural deficits... ...are associated with prenatal blood lead exposure levels on the order of 10 to 15 ug/dl and possibly even lower, as indexed by maternal or cord blood lead concentrations" and that the evidence "supports the conclusion that fetal exposure to lead at relatively low and prevalent concentrations can have undesirable effects on infant mental development, length of gestation and possibly other aspects of fetal development".

The currently available data suggest that the current intervention level of 20 ug/dl is above the blood lead level at which potentially adverse physiological effects may occur. It is therefore prudent to lower children's blood lead levels as much as practically possible.

4.0 LEAD IN THE ENVIRONMENT: SOURCES AND PATHWAYS

4.1 Sources

Lead is a naturally occurring element with many industrial uses. Lead is now the fifth most commonly used metal in the world. The extensive mining and industrial use of lead over the centuries has resulted in greatly increased emissions of lead into the atmosphere. Atmospheric lead is inhaled by humans and animals, or is eventually deposited onto soil, water, and vegetation.

The major source of lead emitted to the environment is the use of leaded gasoline. Up to 90% of the lead emitted into the atmosphere in the U.S. in 1984 was estimated to have originated from gasoline combustion.

Canada is the western world's third largest producer of mined lead, with 311,000 tonnes of primary lead being produced in 1984 (RSC, 1986). In 1982, an estimated 73,000 tonnes of lead were discharged into the Canadian environment, with greater than 83% of this being solid waste (Jaques, 1985).

From a public health perspective, the emission of lead particulates into the atmosphere has the greatest adverse impact. In 1982, it was estimated that 11,500 tonnes of

lead particulates were emitted into the atmosphere with 63% of these emissions resulting from gasoline combustion (Jaques, 1985). Mining and refining of ores accounted for another 18% of the total atmospheric emissions, while the lead production industry itself contributed 9%. Secondary lead smelters per se only contributed 0.1% of the total emissions (RSC, 1986).
Once lead has been emitted into the atmosphere, it is deposited onto soil, vegetation and water and may be re-cycled through environmental pathways and the food chain.

4.2 Pathways of Exposure

Many pathways exist by which lead in the environment may be taken in and absorbed by humans.

4.2.1 Diet

Diet is the primary contributor to blood lead levels in adults, with greater than 50% of an adult's blood lead level attributable to lead uptake from food and beverages. Health & Welfare Canada has estimated that 60% of an urban adult's daily lead uptake originates with diet, while 83% of a rural adult's daily lead uptake results from diet. This variation in the percentage contribution of diet primarily reflects the increased contribution of other sources, e.g. airborne lead, to the urban adult's daily lead uptake.

Health & Welfare Canada (Sitwell, 1987) also estimates that diet contributes from 41%, for urban children, to 73%, for rural children, of the daily lead uptake for a child.

4.2.2 Air

As indicated earlier, the primary source of atmospheric lead in Canada originates from the combustion of leaded gasoline. Automotive emissions of lead increased from 2600 tons in 1948 to 14,360 tons in 1973 (RSC, 1986). As a result of the introduction of unleaded gasoline in 1972, and the reduction in the permissible concentration of lead in leaded gasoline to 0.77 g/L, atmospheric lead emissions from gasoline combustion were reduced by over 50% in the period 1973-1984.

A major reduction in automotive lead emissions is anticipated in 1987 as a result of the lowering of the permissible lead concentration in gasoline to 0.29 g/L. A further reduction in the allowable concentration of lead in leaded gasoline will be implemented in Canada in 1993. At that time, it is expected that the permissible lead level will be approximately 0.026 g/L (the current U.S. standard).

The Royal Society of Canada Report (1986) estimates that typical air lead concentrations in inner city areas of North American and European cities range from 0.5 - 1 ug/m^3, while outer city and rural areas typically have levels of air lead ranging from 0.1 - 0.3 ug/m^3.

Environment Canada has indicated that Canada's annual geometric mean lead concentration in air was 0.27 ug/m^3 in 1982, and that 63% of this lead originated from automobile emissions (Jaques, 1983).

Based on the National Air Pollution Surveillance Annual Summaries for 1984 and 1985, Health & Welfare Canada has

calculated an unweighted arithmetic mean, based on the annual geometric means, for lead in air. Health & Welfare Canada estimated the 1984 arithmetic mean air lead level in Canada to be 0.23 $\pm$ 0.15 ug/m^3, and the 1985 level to be 0.18 $\pm$ 0.12 ug/m^3, and expect that a decline in air lead levels should continue for another four or five years, primarily due to the decrease in automotive lead emissions.

4.2.2.1 Ontario Ministry of Environment Air Lead Surveys

In order to determine ambient airborne lead concentrations in Ontario, the Province of Ontario established air lead monitoring in 1969, and has subsequently expanded these efforts to establish an Ontario Lead Monitoring Network.

Data collected between 1972 and 1982 indicate that airborne lead concentrations in Ontario decreased by 79% over this period, primarily as a result of decreased lead emissions from automobiles (Heidorn and Rohac, 1984).

A summary of air lead data collected between 1983 and 1986 in Ontario indicates that rural areas of Ontario had annual geometric mean air lead concentrations ranging from 0.1 to 0.2 ug/m^3, that urban areas of Ontario unaffected by point-source lead emissions had annual geometric mean air lead levels ranging from 0.1 to 0.3 ug/m^3, and that annual geometric mean air lead levels in the vicinity of industrial point sources of lead ranged from 0.2 to 2.1 ug/m^3 (Kurtz, 1987).

The MOE Air Quality Criterion for a 24-hour sample is 5.0 ug/m^3, while the Air Quality Criterion for a 30-day geometric mean concentration is 2 ug/m^3 (Heidorn and Rohac, 1984).

Air lead levels in the Province of Ontario were assessed in 1984 as part of the Ontario Blood Lead Survey. These levels were assessed for those urban, suburban and rural areas participating in the study. The findings of these air lead studies can be summarized as follows:

1. The highest air lead levels were observed in Toronto, where the mean (both arithmetic and geometric) air lead level was found to be 0.7 ug/m^3;

2. Both urban sites (Toronto and Windsor) had higher maximum air lead levels than both suburban sites. The two rural sites had maximum air lead levels of 0.1 ug/m^3;

3. The percentage of air lead attributable to vehicle exhaust was determined based upon lead/bromine ratios and the percentages of lead in the air attributable to vehicle exhaust were:

   (a) For urban sites:
   Toronto - 85% $\pm$ 5%; Windsor - 80% $\pm$ 5%
   (b) For suburban site - Etobicoke - 73% $\pm$ 5%
   (c) For rural sites:
   Walpole - 67% $\pm$ 5%; Longwoods - 77% $\pm$ 5%

4. The geometric means for rural, suburban and urban air lead concentrations were 0.1, 0.2 and 0.4 ug/m^3 respectively.

4.2.2.2 Contribution of Air Lead to Blood Lead Levels

The Isotopic Lead Experiment in Italy indicated that at least 25% of the blood lead of adults in Turin originated from gasoline lead (Facchetti and Geiss, 1982). The average blood lead level of adult males in Turin was 25 ug/dl, and approximately 6 ug/dl was shown to be directly attributable to gasoline lead.

For adults, the primary intake route of this gasoline lead would be through inhalation of atmospheric lead or dust. The mean air lead concentration in Turin at the time of the study was 1.7 ug/m^3, a level higher than would be found in most North American cities.

Health & Welfare Canada (Sitwell, 1987) estimates that approximately 23% of an urban adult's daily lead uptake comes from the inhalation of air. Lower ambient air lead levels in rural environments leads to the estimate that air contributes only 9% of a rural adult's daily lead uptake. Furthermore, Health & Welfare Canada estimates that only 1-2% of a child's daily lead uptake comes directly from the inhalation of air.

4.2.3 Water

In past decades, lead piping was frequently used in water distribution systems and, consequently, lead in water was a significant dietary source of lead. Lead pipes are no longer installed, but some may still be found in some older water distribution systems. A City of Toronto study of the lead water distribution system indicates

that there are still approximately 75,000 lead service connections in the city, but the study indicates that there is no evidence that any significant amount of lead is entering the water supply (Nixson and Bremner, 1987).

The primary source of lead in drinking water these days originates with the use of leaded solder in distribution systems. The lead in the solder may leach into the water column, especially if the water is "soft" or of a low pH. The leaching effect is usually more pronounced in new houses, and decreases with age as the amount of lead in the solder decreases through the process of leaching.

Health & Welfare Canada estimates that from 1-3% of daily lead uptake comes directly from water.

A Toronto Department of Public Health study in the South Riverdale area of Toronto, conducted as part of the follow-up investigation of children shown to have elevated blood lead levels in its 1984 survey, indicated that lead in drinking water did not contribute significantly to the elevated blood lead levels (Macpherson, 1987(a)).

The Ontario Ministries of the Environment and of Health are planning to conduct a water lead/blood lead survey in selected northern communities in 1987 to examine possible high lead levels in "soft" or low pH water supplies in these communities in Northern Ontario.

4.2.4 Soil/Dust

Ontario Ministry of the Environment studies in the vicinity of lead-emitting industries in Toronto and

Mississauga have shown that extremely high levels of soil lead, as high as 51,000 ppm on industrial land (Rinne, 1986 (b)) and 10,200 ppm on residential land (MOE, 1986(a)), may be found proximate to lead emitting industries. The soil lead levels decrease rapidly with increasing distance from the industry until they reach background urban lead levels (Linzon et al. (1976); Rinne, 1986 (a),(b) & (c)).

Ontario Ministry of the Environment studies in the South Riverdale area of Toronto have shown that, while the soil lead levels are still high, they have dropped in recent years (Rinne, 1986 (a)). A recent assessment by the Phytotoxicology Section of the MOE indicates that the average soil lead concentration at residential sites in the vicinity of the Canada Metal Company that were not included in the earlier soil replacement program has declined approximately 15.9% between 1976 and 1985 (MOE, 1986 (a)).

Similar surveys showed that the average soil lead concentration for 11 sampling stations in the vicinity of Toronto Refiners and Smelters Limited more than doubled from 5190 ppm to 11,745 ppm between 1980 and 1985. Most of this increase was due to markedly high soil lead levels at stations along the southern and eastern perimeter of the Toronto Refiners and Smelters Ltd. property (Rinne, 1986(b)).

The MOE has conducted studies of lead contamination of vegetation and/or soil near the Tonolli Co. of Canada Ltd. and Exide Canada Ltd. in Mississauga annually since 1970. A total of 41 sites has been sampled annually. A comparison of the 1980 and 1985 survey results indicates that the arithmetic mean soil lead concentration in the

vicinity of the two plants has increased by approximately 14% over that five year period reaching 1230 ppm in 1985. Thirty-four of the 41 stations sampled in 1985 exceeded the 500 ppm "upper limit of normal" lead concentration in urban soil (Rinne, 1986 (c)).

4.2.5 Paint Chips

Lead based paint has long been considered to be the major source of high-dose lead exposure and symptomatic lead poisoning for children in the United States. In the past, leaded paints in the U.S. may have contained up to 500,000 ppm lead, but, since 1977, household paint in the U.S. must, by regulation, contain no more than 600 ppm of lead (CDC, 1985). In Canada, paint may contain up to 5000 ppm lead.

Neither the Ontario Blood Lead Study nor the South Riverdale studies assessed the possible contribution of leaded paint to elevated blood lead levels in children, and therefore the possible contribution of leaded paint to elevated blood lead levels in Ontario children cannot be assessed at this time.

5.0 THE RELATIONSHIP BETWEEN SOIL LEAD LEVELS AND BLOOD LEAD LEVELS

Many studies have attempted to estimate the contribution and significance of soil lead to blood lead levels. Unfortunately, these studies are difficult to compare due to many confounding factors such as the age of the children studied, the lack of standardization of sampling methods, and the statistical limitations inherent to each study.

Although the actual contribution of soil lead to children's blood lead levels is highly variable and dependent upon the particular circumstances, the evidence is substantial that children's blood lead levels vary directly with soil lead levels.

Health & Welfare Canada (Sitwell, 1987) estimate that up to 56% of a child's daily lead uptake may come from dust or dirt. The relative contributions of exterior and household dust and of soil are difficult to separate and define due to their close relationship and the many confounding variables.

5.1 International Studies

Charney et al. (1980) conducted a case control study of children aged 1-1/2 to 6 years, and indicated that hand lead level, house dust lead level and lead in soil were very important factors contributing to observed variations in blood lead levels.

Rabinowitz et al. (1985) also showed that lead levels in indoor dust and outdoor soil were predictive of blood lead levels in Boston infants (urban or suburban) aged two years or less.

A study by Brunekreef et al. (1983) in the Netherlands, showed that blood lead levels increased with increasing outside dustfall and with increased lead levels on children's hands.

Charney et al. (1983) in a carefully designed study, examined the contribution of house dust to the elevated blood lead levels of children (aged 15-72 months) who had been examined at the Lead Poisoning Clinic in Baltimore and had been found to have blood lead levels between 30 and 49 ug/dl. The study indicated that ingestion of lead-contaminated house dust is a very important factor in elevating children's blood lead levels, and that removing lead-contaminated house dust can significantly lower blood lead levels.

This study also indicated that long lasting benefits from "cleaning" a house to remove lead-contaminated dust may be difficult to achieve unless other remedial actions, such as soil replacement, are undertaken. Dust lead levels in experimentally cleaned houses returned to nearly the previous high values within two weeks if no other remedial action was taken. It would appear likely that frequent, thorough house dust removal may be necessary if the source(s) of the lead-contaminated house dust is not controlled.

The impact of urban lead exposure on the blood lead levels of children aged 5 or less is being examined in a prospective cohort study being conducted in Cincinnati, Ohio. Bornschien et al. (1986) have shown that 38% of the variation in blood lead levels of children 18 months of age was accounted for by hand lead and dust lead, and that an increase in soil lead from 0-1000 ppm resulted in an indirectly mediated increase in blood lead of 6.2 ug/dl. This study also indicated that exterior environmental (e.g. soil) lead contributes to blood lead through the pathway soil lead --> dust lead --> hand lead --> blood lead.

In contrast, a study by Barltrop et al. (1975) in Derbyshire, England, found that soil lead contributed only 0.6 ug/dl to children's (age 2-5) blood lead for each 1000 ppm increase in soil lead level. This study was conducted in a rural area where industrial point sources of lead no longer existed. Lead contaminated soil was covered by vegetation, which may have resulted in the soil lead being less accessible to children.

The U.S. EPA has assessed available studies on the relationship between soil lead and blood lead levels in children, and have estimated that a child's blood lead may increase by 0.6-6.8 ug/dl for each increase of 1000 ug/g in soil lead concentration (EPA, 1986).

5.2 Ontario Studies

In order to assess the potential contribution of lead contaminated soil to elevated children's blood lead levels in Ontario, it is essential to examine the evidence provided by studies conducted specifically in Ontario.

5.2.1 The Ontario Blood Lead Study

In 1984, the Ontario Ministries of the Environment, Health and Labour coordinated a study into blood lead and associated risk factors in Ontario children (Duncan et al. 1985)

The Ontario Blood Lead Study tested children from urban, suburban and rural areas of the province, with no known

exposure to industrial point sources of lead. A total of 1269 children, age 6 and under, were tested, with the majority of the children (1155) aged 4 to 6.

Soil sampling and analysis was conducted by the Phyto-toxicology Section of the MOE. Soil samples (0-5 cm depth) were collected from a minimum of three locations per school-yard, from unpaved, unsodded play areas where children would have frequent, direct contact with the soil. Soil lead levels in unsodded, ungrassed areas appear to be lower than soil lead levels in adjacent grassy sites.

The study found that urban children had the highest geometric mean blood lead levels (12.0 $\pm$ 4.4 ug/dl), while suburban children had higher geometric mean blood lead levels (10.0 $\pm$ 3.5 ug/dl) than rural children (8.9 $\pm$ 3.9 ug/dl).

A total of 65 risk factors were assessed in the Ontario Blood Lead Study, and, of these, proximity to industries and gas stations, soil lead, traffic density, age and socio-economic status were found to account for 20% of the observed variability of blood lead levels. It is important to note that this study did not evaluate the contribution from dietary intake, the contribution from interior house dust, or the contribution of lifestyle factors to elevated blood lead levels.

5.2.2 Toronto Department of Public Health Studies

Although emissions from lead industries only contribute a small percentage of the total lead emissions to the atmosphere annually, these emissions are usually confined to a limited area where they may significantly impact upon air lead and soil lead levels. Consequently, children living in an urban area in close proximity to an industrial lead source may be exposed to air lead and soil lead levels significantly higher than the average urban child.

The Toronto Department of Public Health has expressed particular concern about the potential impact of elevated air lead and soil lead levels upon the health of young children residing near a lead-emitting industry. Consequently, blood lead surveys of residents in the vicinity of the Canada Metal Company plant in the South Riverdale area of Toronto were conducted as early as 1973 and 1974.

Since 1982, the Toronto Department of Public Health has conducted annual blood testing of children under age 6 in a "high risk" area of South Riverdale. The designated blood lead testing area was delineated as being whole, or parts of blocks, in that area where soil lead levels were found to frequently exceed 1000 ppm based upon Ministry of the Environment soil sampling surveys.

These surveys indicated that children in the designated testing area of South Riverdale had higher blood lead levels than other urban children who did not live near a major industrial lead source. For example, in 1984, children living in South Riverdale had a mean lead level of 13.99 $\pm$ 1.58 ug/dl (Macpherson, 1987(a)), as opposed

to urban children surveyed in the Ontario Blood Lead Study who had a mean lead level of 12.0 ± 4.4 ug/dl (Duncan et al. 1985). Of greater significance, perhaps, was the finding that approximately 18% of the children tested in South Riverdale had blood lead levels exceeding the 20 ug/dl intervention level. In contrast, only 5% of urban children tested in the Ontario Blood Lead Survey had blood lead levels exceeding 20 ug/dl.

When children of the same age and sex are compared, (i.e., four and five year old, boys and girls), the South Riverdale children have blood lead levels 3 ug/dl higher than their urban cohort, rather than the 2 ug/dl reported in the Toronto Department of Public Health comparison study (SRCHC, 1987). In addition, the South Riverdale deputation suggested that the different blood collection methods employed in the two studies and the difference in socio-economic status between the subject groups, may both contribute to a narrowing in the observed difference in blood lead levels between the study groups. On these bases, the South Riverdale Community Health Centre assessment concludes that the difference between South Riverdale children's blood lead levels and those of other urban Ontario children is at least 3 ug/dl.

Soil lead levels in the South Riverdale school yards were found to be low and comparable with those from the urban school yards measured in the Ontario Blood Lead Study. The soil lead levels used in the correlation were analysed in soil samples collected from front and backyards of residential properties. The high residential soil lead levels, with a geometric mean of 641 ppm, are characteristic of proximity to a point source of lead. There was a range in soil lead concentrations, within the South Riverdale study area, on

residential properties where soil lead was measured and where children resided; 32.6% of these properties had weighted average soil lead levels below 500 ppm; 27.4% had levels between 500 and 799 ppm; 16.8% had levels between 800 and 999 ppm; and 23.2% exhibited soil lead levels at or above 1000 ppm (Macpherson, 1987(a).

The presence of pets in a household was also found to be related to elevated blood lead levels in the children. In 1984, approximately one-third of surveyed children lived in homes where dogs or cats were kept as pets, and approximately two-thirds of the children with a screening blood lead level of $\geq$ 20 ug/dl had such pets (MacPherson, 1985).

When the population of children in South Riverdale were compared with all of the children in the Ontario Blood Lead study, a positive correlation between soil lead and blood lead was evident. However, there was no correlation between an individual child's elevated blood lead level and the corresponding residential soil lead level. This may be taken as a further indication that a child's blood lead level is influenced by the lead in the community as a whole and that multiple pathways are involved.

In order to determine the primary factors that most influenced the observed differences in blood lead levels, the Toronto Department of Public Health has conducted a comparison of the 1984 South Riverdale and Ontario Blood Lead Studies (Macpherson, 1987(a)). The key findings of this comparison study may be summarized as follows:

(a) Children living in an area impacted by an industrial lead source have significantly higher

blood lead levels than children living in a comparable area without an industrial source.

(b) Children living in South Riverdale had a higher (2-3 ug/dl) mean blood lead level than did children in other urban areas of the province.

(c) More than 18% of the children in South Riverdale had blood lead levels exceeding the 20 ug/dl action level, while only 5% of urban children studied in the Ontario Blood Lead Study had blood lead levels exceeding 20 ug/dl.

(d) In South Riverdale, levels of lead in residential soil (weighted geometric mean = 641 ppm) were markedly higher than the lead levels in the school yard soil sampled in other urban areas in the province (weighted geometric mean = 47 ppm).

(e) The air lead level in South Riverdale during the survey period was higher than the air lead level in other urban areas (0.8 ug/m^3 as opposed to 0.5 ug/m^3).

(f) Although no single environmental factor alone was sufficient to predict children's blood lead levels, four factors were found to account for 21% of the variance in children's blood lead levels. These factors were:

(i) Immediate proximity to numerous industries;
(ii) Neighbourhood traffic density;
(iii) Socio-economic status of family; and
(iv) Soil lead level in the child's immediate environment.

It once again must be noted that in the South Riverdale study, as well as the Ontario Blood Lead Study, the influence of diet, personal hygiene, lead content of paint in the immediate environment, lead in dustfall and lead in house dust were not examined.

Although dietary lead intake was not evaluated in either study, it is considered unlikely that dietary lead intake differed significantly between the South Riverdale children and the urban children studied in the Ontario Blood Lead Study. However, the influences of lead in dustfall, house dust lead , and possibly paint chip lead, may play significant roles in the observed differences in blood lead levels.

The Toronto Department of Public Health has also conducted blood lead surveys in the Niagara Neighbourhood of Toronto near Toronto Refiners and Smelters Ltd., a secondary lead smelter (Macpherson, 1987(b)). None of the 23 children screened in 1984 (all of whom lived more than 200 m from the lead company property) had confirmed elevated blood lead levels (i.e. 20 ug/dl or greater).

The 1985 survey assessed blood lead levels in seven children under six living within 200 m of the lead company property and found one child to have a confirmed blood lead level equal to the 20 ug/dl action level. (Macpherson, 1987(b)).

The Toronto Department of Public Health has compared the findings of the 1984 and 1985 Niagara Neighbourhood blood lead studies with the findings of the Ontario Blood Lead Study and concluded that the findings suggest that "the

few children under six years of age living immediately adjacent to Toronto Refiners and Smelters may have higher blood lead levels than Toronto children not exposed to a point source of environmental lead." (Macpherson, 1987(b)).

5.3 The Potential Contribution of Soil/Dust Lead to the Tolerable Daily Intake of Lead for a Child

Epidemiological studies often fail to detect the significance of certain variables to the individual child. As mentioned earlier, soil lead/blood lead correlations are particularly difficult due to many confounding variables, one of which is the extent of a child's mouthing activities and the resultant intake of lead contaminated soil or dust.

The Royal Society of Canada report states that the direct ingestion of dust or soil is "the most difficult route to evaluate", however this route is "one of great potential importance, especially for children" (RSC, 1986).

The FAO and WHO have recommended a maximum tolerable daily intake of 7 ug/kg body weight/day of lead, which translates to approximately 40 ug/day for an infant, 100 ug/day for a two-year old, and 125 ug/day for a 5 year old (FAO/WHO, 1972).

Certain regulatory agencies (e.g. U.S. FDA) have recommended a maximum tolerable daily intake of 100 ug of lead per day for children under the age of six.

Day et al. (1975) estimated that 100 mg of dust per day could be ingested by an average child through the process of eating sticky candy. Based upon the findings of this study, the U.S. EPA considers 100 mg/day to be a reasonable estimate of the amount of dust ingested by a typical child. Using this estimate, it can be determined that the ingestion of 100 mg of dust, containing 500 ppm lead, would contribute 50 ug of lead, one-half of the tolerable daily intake for a child.

Both atmospheric lead and soil lead contribute to dust lead levels (see Figure 1) and the percentage contribution of atmospheric lead and soil lead to dust lead varies from site to site, dependent upon such factors as type and amount of vegetation, atmospheric lead levels and deposition rates, soil lead levels, climate, etc.

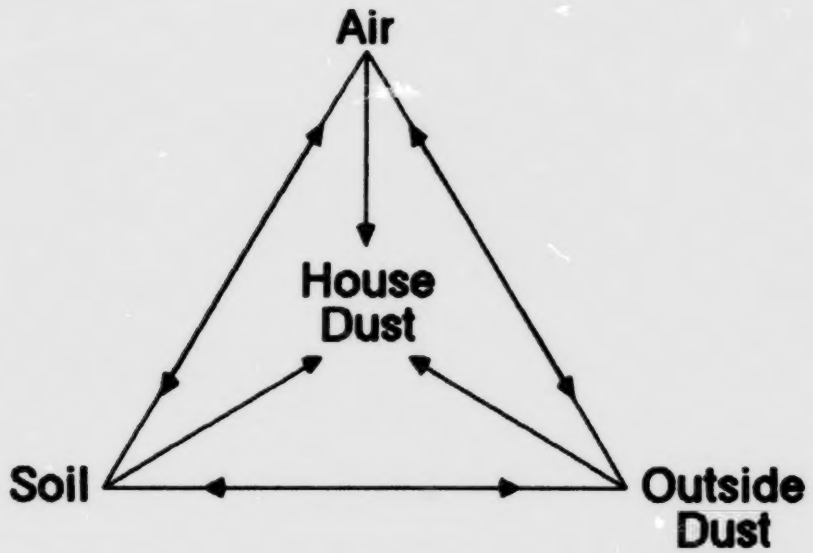

FIGURE 1
The Relationship Between Air Lead, Soil Lead and Dust Lead

5.4 The Influence of Soil Lead on Blood Lead Through the Consumption of Vegetables Grown in Lead Contaminated Soil

The aforementioned studies primarily assessed the influence of environmental lead on blood lead levels as a result of the ingestion or inhalation of lead-contaminated air, soil or dust.

In addition to this pathway, soil lead may also contribute to the body burden of lead through the dietary pathway. Root and leafy vegetables, grown in lead-contaminated soil may contain residues of lead. Health & Welfare Canada has indicated that the daily consumption of fruit and vegetables containing greater than 0.5 ug/g may contribute an inordinate proportion of lead to the diet, and have, therefore, established a 0.5 ug/g as a maximum tolerable level for lead in commercially available fruit and vegetables.

Data collected by the Ministry of the Environment indicate that root or leafy vegetables grown in soil containing more than 500 ppm lead are likely to contain levels of lead greater than 0.5 ug/g, while root and leafy vegetables grown in soil containing less than 500 ppm lead usually have lead levels below 0.5 ug/g.

At the present time, decommissioning guidelines (for the restoration of industrial property) for a number of contaminants in soil, including lead, are being developed by the Ministry of the Environment.

Based upon the above data on lead levels in vegetables, and on the findings that 500 ppm soil lead represents the lowest concentration at which growth effects on sensitive plant species have been observed, the MOE Phytotoxicology Section has recommended 500 ppm as a soil lead decommissioning guideline for industrial property being redeveloped into residential property or garden allotments, and 1000 ppm for the restoration of industrial property for other uses (Rinne et al. 1986).

In addition, 500 ppm is the "upper limit of normal" lead concentration in urban soils in Ontario not directly impacted by an industrial point source emission of lead (see Appendix 12.1 for definition of 'upper limit of normal').

6.0 RECOMMENDED SOIL LEAD/DUST LEAD GUIDELINES IN OTHER JURISDICTIONS

The British Inter-Departmental Committee on the re-development of contaminated land (ICRCL, 1983) has recommended 500 ppm lead as a "trigger concentration", below which a site could be regarded as uncontaminated, for land to be redeveloped for domestic gardens and allotments. Additionally, they have recommended 2000 ppm as a "trigger concentration" when the proposed use of the decommissioned land is for parks, play fields and open spaces.

The Greater London Council (GLC, 1980) has recommended 5000 ppm as an action level for lead in dust. Dust lead levels in urban areas of the United Kingdom have been found to range from 1400 to 280,000 ppm (Caswell, 1985; Wixson and Jennett, 1986).

Many jurisdictions in the United States are currently in the process of reviewing available data in efforts to establish soil lead guidelines.

Davies and Wixson (1986), at the 20th Annual Conference on Trace Substances in Environmental Health, recommended 1000 ppm lead in soil as prudent critical regulatory limit. Wixson and Jennett (1986), at the Mexico-United States Symposium on Environmental Engineering and Natural Resources Management, recommended interim guidelines of 500 ppm lead, for soils that are to be used for growing vegetables, and 1000 ppm lead for soils for industrial, open space or park land purposes.

Many individual states in the U.S., as well as the U.S. EPA, are currently in the process of establishing interim soil lead guidelines or standards.

At this time, it is unclear what soil lead guidelines/ standards will be established within various jurisdictions in the U.S., but it is anticipated that guideline levels will be established between 500 and 1000 ppm, dependent upon the proposed uses of the soil and site-specific considerations.

7.0 DISCUSSION

In its attempt to recommend a "scientifically defensible soil removal guideline" for lead-contaminated soil, the Committee has reviewed the available information on the toxicology of lead and on the environmental sources and pathways of lead uptake that may significantly contribute to blood lead levels.

It is evident that the available data are insufficient to establish a "scientifically defensible" soil removal guideline at this time, if the phrase "scientifically defensible" is interpreted to mean the necessity of proof that:

a) The influence of soil lead, above a guideline level, would result in a statistically significant increase in blood lead levels in a population of children at risk;

b) The removal of lead-contaminated soil would result in a statistically significant reduction in blood lead levels; and

c) The potential for adverse health effects, due to elevated blood lead levels, is sufficient to warrant remedial action.

This type of stringent definition of "scientifically defensible" requires a degree of proof that is almost impossible to establish in most areas of science.

Therefore, although current evidence may not allow establishment of a "scientifically defensible" guideline as defined above, the Committee feels that the available information is adequate to provide advice and to recommend appropriate remedial environmental actions, including the recommendation of reasonable soil lead guidelines.

The following discussion summarizes the Committee's assessment and interpretation of the scientific evidence detailed earlier in the report.

7.1 Toxicology of Lead

Lead is a toxin, known to have adverse effects on several systems in the body.

Available medical evidence indicates that lead, even at levels previously thought to be "safe", is toxic to the developing central nervous system, impairs haem biosynthesis, and may have adverse effects on neuropsychological development, stature and hearing in children.

The effects of lead toxicity are clinically silent and difficult to recognize. The best indicator of toxicity is the blood lead level, which reflects the total body burden.

The Toronto Department of Public Health has established 20 ug/dl blood lead as an 'alert' or intervention level, at which concern about the potential adverse health effects, to children under six years of age and women of child-bearing age, may warrant remedial action.

There is agreement that, within the non-occupationally exposed population, the foetus and children up to about six years of age constitute the population most at risk from lead exposure.

Having reviewed the medical evidence available, including evidence that was not available at the time the intervention levels were set, the Lead in Soil Committee has concluded that there appears to be no margin of safety inherent to these 'alert' levels, and that, although much of the recent evidence on the physiological effects of blood lead levels of 8-15 ug/dl still has to be confirmed, there is certainly reason for concern about blood lead levels lower than 20 ug/dl.

Consequently, the Committee concludes that it is a prudent and responsible policy to reduce blood lead levels to as low a level as possible.

7.2 Lead in the Environment - Sources and Pathways

Exposure to lead may occur through a number of pathways. Figure 2 illustrates the major environmental lead sources and exposure pathways and the fate of ingested or inhaled lead.

The primary source of body burden lead is food. Dietary sources contribute, on average, approximately 40-60% of the daily lead intake.

The inhalation of lead in air and the ingestion of lead in water, soil or dust, are the other primary pathways through which the body takes in lead. These environmental pathways contribute the remaining 40-60% of the daily lead intake.

Factors such as climate, age, socio-economic status, and the levels of lead in air, soil and dust are variables that influence the proportion of daily lead intake contributed by each pathway.

For example, air lead levels in urban areas are higher than in rural areas and therefore the relative contribution of lead uptake through inhalation is higher for urban dwellers than for rural dwellers.

For rural adults and children, the largest percentage of lead uptake is through the diet.

For urban adults, approximately 40% of lead comes from inhalation of lead in air and 60% from ingestion of lead in the diet, with negligible contributions from water or soil or dust.

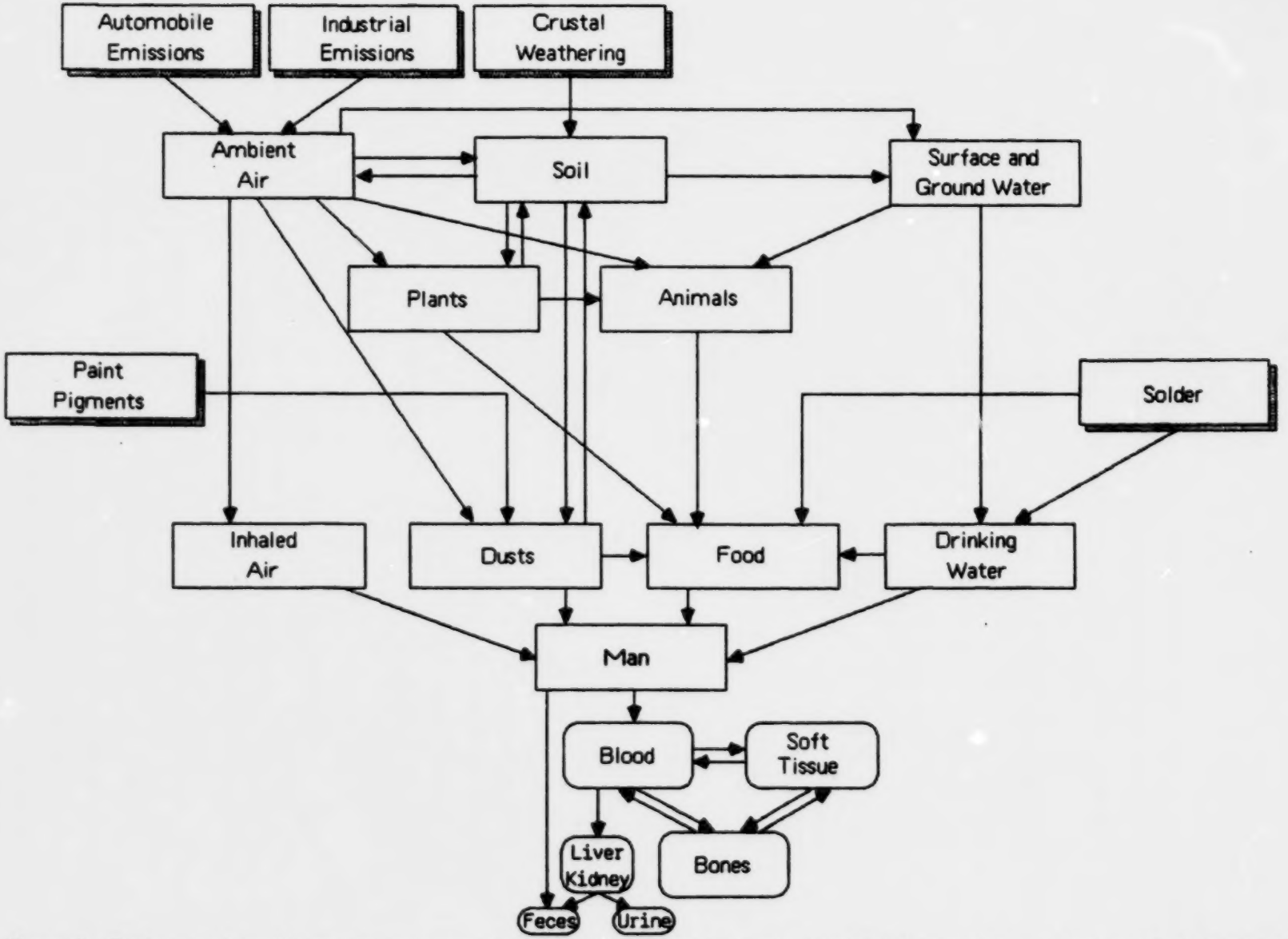

Figure 2. Pathways of lead from the environment to man, main compartments involved in partitioning of internal body burden of absorbed/retained lead, and main routes of lead excretion. Based on US EPA Air Quality Criteria for Lead, June 1986.

Approximately 40% of the daily lead uptake by urban children comes through diet, while approximately 60% comes directly through environmental pathways.

In the Ontario Blood Lead Study, 1984, it was estimated that 80% to 85% of the lead in urban air, not affected by a major point source emission of lead, was attributable to automotive exhaust. With the federal initiatives to reduce lead in gasoline, it is estimated that urban air lead levels away from a point source should be reduced over the next few years. It is expected that blood lead levels in the general population will fall consequent to the decreased emissions.

7.3 Relationship between lead in soil/dust and lead in blood

Many studies have attempted to estimate the contribution and significance of various sources of lead to blood lead levels. A number of these studies have looked at the contribution of soil lead, lead in house dust and lead in outside dust to children's blood lead. Most of these studies have shown that there is a statistically significant relationship between soil lead and children's blood lead.

There are a number of confounding factors that make drawing of conclusions from these studies very difficult. These factors include the following: the interaction of the lead pathways; the type of vegetation cover; the age of the children; and the variation in sampling methods and and socio-economic factors. In addition, as discussed in Section 7.2, the multiple, interactive environmental pathways of lead exposure make it extremely difficult to assess the specific contribution of any individual pathway to blood lead levels. Epidemiological studies are extremely complex and costly and, to date, no

single epidemiologic study has assessed the specific contribution of each environmental variable. The inherent difficulties associated with the interpretation and extrapolation of the findings of epidemiological studies on a contaminant with several environmental pathways, where all variables cannot be adequately "controlled", severely limited the Committee's ability to establish a "scientifically defensible" soil lead guideline.

7.3.1 International Studies

In its efforts to recommend a soil lead guideline, the Committee has reviewed international evidence, as well as available Ontario and Canadian evidence, on the relationship between environmental lead levels and blood lead levels. This required a multi-media assessment approach that focused upon the contribution of air lead, soil lead and dust lead to blood lead levels.

Studies in the United States have shown that soil lead levels are predictive of blood lead levels. Blood lead levels have been observed to increase between 2.2 and 6.8 ug/dl per 1000 ppm soil lead. Some of these studies have also evaluated the relationship between lead-contaminated house dust and blood lead levels and have found statistically significant correlations. These studies suggest that the most likely environmental pathway, leading to increased blood lead levels in children between 12 and 24 months of age, is the soil lead $\longrightarrow$ house dust $\longrightarrow$ hand dust $\longrightarrow$ blood lead pathway.

In particular, the studies by Charney *et al*. in Baltimore, and Bornschein *et al*. in Cincinnati indicate that the thorough removal of lead contaminated house dust can significantly lower blood lead levels by interrupting

this pathway at a critical point. These studies suggest that the removal of lead contaminated soil without thorough house-cleaning does not significantly affect blood lead levels. In the Cincinnatti study, socio-economic and climatic factors played significant roles in the environmental lead pathway. The soil lead was not covered by vegetation and was mobile in the form of dust, which could easily recontaminate the houses. In addition, most of the dwellings had no front yards and recontamination of the houses by street dust was also a contributing factor. The old, inner city housing, in which many of the children in the Cincinnatti study resided, was considered inadequately rehabilitated and in a chronic state of disrepair (Bornschein, et al., 1986). The condition of housing, as well as socio-economic factors, have been found to greatly influence blood lead levels (Clark et al. 1985; Bornschein et al. 1985).

Clark and Bornschein (1987) postulated that while "the removal of lead containing soils is unlikely to be an important intervention event in reducing blood lead" soil removal would "be considerably more effective if combined with efforts to reduce levels of lead in dust both interior and exterior to houses. Dust abatement efforts, in turn, would be more effective if coupled with actions to reduce the primary sources of lead in dust".

The Barltrop studies in England suggested that blood lead levels increased by only 0.6 ug/dl per 1000 ppm soil lead. Why do the soil lead levels in Derbyshire appear to contribute to such a lesser extent to blood lead levels than is evident in the U.S. studies? The answer appears to be associated with the availability of this soil lead to children. In Barltrop's studies, soil lead levels were as high as 30,000 ppm but the study area was

covered with grass. It appears that the soil lead was not in a mobile dust form and, consequently, did not affect blood levels as significantly as in the U.S. studies. Barltrop et al., (1975) concluded that "many factors may influence the absorption of lead in dust and soil", and that the study results could be explained only if "minute amounts of soil are ingested - even by children who put soil directly in their mouths, or alternatively, by very low absorption of lead from soil in the gut".

Obviously, socio-economic factors, environmental factors, and other "site specific" or community factors, play significant roles in determining the availability of soil lead to a child, and that these factors, and their influence on the environmental lead/blood lead pathway, are likely to vary from site to site.

The observation that approximately two-thirds of the children in South Riverdale, with blood lead levels at or exceeding 20 ug/dl, had dogs or cats as pets is suggestive of the fact that these pets increase the availability of lead to children. This may be due to the increased tracking of soil/dust into the house by these pets, or to the increased transmission of soil/dust to children's hands due to their handling of the animals.

Another site-specific factor that should be assessed is the role or contribution of leaded paint chips.

In many of the U.S. studies, ingested paint chips, containing a very high lead concentration, played a significant role in increasing blood lead levels. These paint chips, from paint peeling either inside or outside the house, contributed significantly to both house dust

levels and to the soil lead levels in the immediate vicinity of the house and could significantly affect the environmental lead/blood lead pathway.

Due to the many site-specific variables that affect the apparent relationship between soil lead levels and blood lead levels in the international studies examined, extrapolation of the findings of these studies to the Ontario situation must be done cautiously.

Another complication lies with the interpretation of the statistical analyses of epidemiological studies. As mentioned earlier, blood lead levels have been observed to increase between 2.2 and 6.8 ug/dl per 1000 ppm soil lead in U.S. studies. This may seem to imply that removal of soil lead would lead to a reduction in blood lead levels equal to the magnitude of the observed relationship. However, an understanding of the relationship of environmental pathways of lead, and of the limits of statistical interpretation are critical to the interpretation of the findings of epidemiological studies designed to evaluate the relationship between environmental lead sources and blood lead levels. Regression analyses, performed on the data generated in epidemiological studies, may be used to identify influential variables, but these analyses are limited in their capacity to assess the magnitude of the affect of the variable. Similarly, where many variables interact, regression analyses may be limited in their ability to differentiate the relative contribution of each significant variable, or the affect of removal of a single variable.

This may best be explained by the following example. In a situation where elevated air lead (including dustfall

lead) levels contribute to elevated soil lead levels, and the air lead and soil lead contribute to house-dust lead levels, regression analyses of air lead and blood lead data may indicate a strong relationship. Similarly, regression analyses of soil lead and blood lead data would also show a strong relationship, as would the analysis of house-dust and blood-lead data.

Each of these analyses shows a strong relationship between an environmental lead source and elevated blood lead levels, but this relationship cannot be extrapolated to prove that removal of that particular environmental source alone will result in a predictable lowering of blood lead levels. For example, if all air lead contribution was eliminated, blood lead levels may not show any significant decrease because the reservoirs of lead in soil and dust could still provide significant lead exposure. Similarly, if soil lead is removed, but house-dust and air lead levels remain constant, then blood lead levels may not drop significantly.

[Note: See Appendix 12.6 for additional information on analysis of statistics].

7.3.2 The Ontario Situation

The Ontario Blood Lead Study indicated that children under six years of age living in urban centres, and not in the proximity of a point source of lead, had a mean blood lead level of approximately 12 ug/dl. Studies conducted by the Toronto Department of Public Health in the South Riverdale area of Toronto have shown that children under the age of six, living in proximity to a secondary lead smelter, have mean blood lead levels of approximately 14-15 ug/dl.

Available scientific evidence indicates that the higher blood lead levels observed in children in South Riverdale are due to environmental influences. The influences of dietary and water borne lead were considered unlikely to have contributed to the observed difference in blood lead levels.

Historically, air lead levels in the vicinity of the secondary lead smelter have been significantly higher than those observed in other urban areas of Toronto. Deposition of this atmospheric lead, along with the deposition of other atmospheric lead that originated primarily from the combustion of leaded gasoline, has been shown by Ontario Ministry of the Environment surveys to have resulted in significantly higher soil lead levels in the proximity of the smelter.

The Toronto Department of Public Health comparison of the Ontario Blood Lead Survey and the 1984 South Riverdale Blood Lead Survey showed that four of the factors studied in these surveys, namely traffic density, socio-economic status, proximity to industry, and soil lead, were significantly correlated, statistically, with the increased blood lead levels observed in South Riverdale. Consequently, the Toronto Board of Health has recommended that soil removal be undertaken in the South Riverdale area as a remedial action in the expectation that such action would result in lowering the blood lead levels in children in that area.

As mentioned previously, neither the Ontario Blood Lead Study nor the South Riverdale study was specifically designed to assess the influence of all environmental variables. Neither study assessed the contribution of house-dust lead or leaded paint chips to the observed

blood lead levels, and consequently, the possible contribution of these factors can only be a matter for conjecture.

Based upon the available evidence, it is likely that air lead, soil lead, and house-dust lead all play roles in the elevated blood lead levels observed in children in South Riverdale; however, the relative contribution to blood lead levels from each source cannot be ascertained.

The available evidence does indicate that if air lead, dustfall lead emissions, and soil lead levels in the South Riverdale area are reduced to "urban background" levels, and if residual house-dust lead is thoroughly removed from the residences, the observed blood lead levels in the South Riverdale area would be likely to drop to "urban background" levels.

From the above assessment, it is evident that removal of soil lead, as a sole remedial measure, is unlikely to decrease blood lead levels to "background" levels.

Another factor that must be considered in the potential contribution of soil lead to blood lead levels is the direct ingestion of dust. Although the removal of soil lead without other remedial action may not significantly affect the air lead ⟶ soil lead ⟶ dust lead pathway, it would substantially reduce the lead contribution from soil ingested directly. Some children, particularly those exhibiting pica, may ingest large quantities of soil, and reducing soil lead levels would likely lower the blood lead levels of those children. Although the geometric mean blood lead level of children in the community may not show a significant reduction as a result of reducing the influence of the direct ingestion

pathway, the number or percentage of children with blood lead levels above the 'alert' level may be substantially reduced if direct ingestion of soil is a major factor contributing to those elevated blood lead levels.

Two major complications exist that severely hamper the assessment of the contribution to blood lead levels of the direct ingestion of dust/soil. Firstly, estimates of the amount of dust/soil ingested by children are speculative and ingested amounts may differ by orders of magnitude from child to child. Secondly, the amount of dust/soil lead absorbed by children is unknown, and the factors that may influence absorption rates of dust/soil lead are subject to conjecture. Both Health and Welfare Canada and the U.S. Environmental Protection Agency estimate that about 30% of ingested dust/soil lead is absorbed.

Due to the uncertainties involved in current estimates of the average daily intake of dust/soil and the amount of dust/soil lead absorbed from the gut, and considering that dust/soil ingestion habits vary significantly from child to child, the magnitude of the blood lead reduction that might be realized by reducing the lead levels of soil cannot be accurately predicted.

The Committee also reviewed the basis for the proposed soil lead guideline for soils in which root and leafy vegetables are grown, and concluded that the proposed guideline level was appropriate, based on current scientific evidence.

In addition, the Committee assessed whether or not the vegetable growing guideline could be extrapolated and used as the basis for a soil lead guideline in urban areas such as South Riverdale.

The Ontario Blood Lead Study and the Toronto Department of Public Health studies did not evaluate home grown produce as a source of lead. However, the Committee agreed that the observed elevated blood lead levels in the South Riverdale children were not likely due to differences in dietary intake of lead.

The most likely source of ingested lead was from dust lead which originates from a combination of atmospheric lead and soil lead.

Some members of the Committee felt that residents in areas such as South Riverdale should be able to grow produce in home gardens without concern about elevated lead intake. Therefore, they feel the soil lead guideline should be set at 500 ppm to accommodate this use of residential property.

Other members of the Committee felt that the soil lead guideline should be based on a concern for the contribution of soil lead to blood lead levels through the dust lead exposure pathway. However, available scientific evidence is not sufficient to pinpoint an appropriate soil lead level for this pathway. Therefore, these Committee members conclude that the soil lead guideline should be established between 500 and 1000 ppm based on site-specific socio-economic and technical factors.

The Committee as a whole agree that actions to reduce the dust lead pathway are appropriate to reduce blood lead levels in children in South Riverdale. Therefore, most Committee members have concluded that a reduction in lead dust deposition and removal of accumulated environmental and residential dust in the area are essential to maximize the health benefits of remedial actions.

8.0 RECOMMENDATIONS OF THE ROYAL SOCIETY OF CANADA AND OF THE TORONTO BOARD OF HEALTH

The Lead in Soil Committee reviewed the recommendations of the Royal Society of Canada governing removal of contaminated soil. These recommendations were as follows:

"14. Removal of lead-contaminated soils or other surface materials should be undertaken from the following sites:

- former lead-processing, lead-using or lead-accumulating industrial plants, where soil lead levels exceed those specified in recommendation 16
- residential, recreational or institutional land (or land to be converted to these uses) contaminated by lead above the level specified in recommendation 16

15. Guidelines governing such removal should cover the following points:

- each case should deal with the specific conditions applicable to each site (i.e. in a site-specific fashion)
- in the case of soil removal from hot spots surrounding specific industrial sites, there should be evidence of significant elevation (in the order of 3 ug/dL) of blood lead levels among children of 6 years of age or younger above those typical of urban areas elsewhere
- the disposal site should be specified, and should be environmentally acceptable

- the replacement soils (or other materials) should have lead concentrations and acidity below specified levels

16. In the decommissioning of old industrial plants and the cleaning up of contamination around existing plants, the following conditions should apply:

    - soil lead levels of up to 500 ug/g are acceptable for residential areas and for garden and allotments
    - levels up to 1000 ug/g should be acceptable for parklands and other areas to which children may have intermittent access
    - soil removal, if necessary, should be carried out to a depth of 30 cm

Experience suggests that these measures may be ineffective if current deposition rates are high (as they are likely to be until the new regulations on lead in gasoline take effect in late 1987)."

In addition, the Committee considered the recommendations of the Toronto Board of Health governing the removal of lead contaminated soil. In 1985, the Toronto Board of Health recommended that lead contaminated soil should be replaced if the conditions, including the following, were met:

1. Children aged 0-5 are regularly exposed to the soil;
2. A representative sample of the children indicates a mean blood lead higher than the comparable Ontario Blood Lead Study results or other acceptable survey results; and
3. The soil lead will not quickly reaccumulate.

In March 1987, Toronto City Council requested that the Ontario Minister of the Environment take several actions, including the following:

1. Replace all residential soil in the South Riverdale designated blood testing area containing greater than 500 ppm lead as a highly desirable option;
2. Commence soil replacement in 1987, with completion of the entire program no later than 1988;
3. Plan and budget for final cleaning of all residences where soil is replaced; and,
4. Develop an enforceable standard for lead in dustfall such that soil lead will not accumulate over 500 ppm in residential areas.

(See Appendix 12.5 for a full list of the requested actions).

In general, the Committee agreed with the recommendations of the Royal Society of Canada with some exceptions and reservations:

1. With regard to Recommendation 15 and the need for evidence of the elevation in blood lead levels among children, the Committee made note that in some cases, (e.g., the Niagara Neighbourhood), the data necessary to establish a statistically significant mean blood lead level above an urban cohort may not be possible. In the Niagara Neighbourhood, this is because few children reside in the area of high soil lead contamination.

   In such cases, provisions should be made for a site-specific evaluation and clean-up if necessary, of the potential exposure. The presence of too few children for meaningful statistical analysis should not prevent remedial action where warranted.

2. In considering Recommendation 16, the Committee noted that testing of soil in 1985 (where limited

soil replacement had been carried out in 1977 and 1978), in areas of South Riverdale showed increases in soil lead levels above the 1978 post-replacement levels. These soils had been replaced to a depth of 15 cm.

Soil samples from the replacement sites collected at depths of 0 to 5, 5 to 10, and 10 to 15 cm, showed increasing concentrations of soil lead with depth. The lower lead concentrations at the surface reflect the impact of the cleaner replacement soil.

Soil samples from the same general area, for which there was no known record of replacement, showed generally declining surface soil lead levels over the same time period.

These data suggest that the apparent increases in surface soil lead concentration post-replacement is likely a result of contaminated soil at lower deptns mixing with the replacement soil.

Therefore, the Committee concurs with the Royal Society of Canada's recommendation that soils should be replaced to a depth of 30 cm instead of the 15 cm used in the previous cleanup.

3. In reviewing Recommendation 16, the Committee feels that the excavated soil should be subjected to the leachate tests prescribed in Regulation 309 of the Ontario Environmental Protection Act. This will determine whether or not it is a hazardous waste as defined by that regulation.

If it is not judged to be a hazardous waste, then disposal in a municipal land fill site is recommended. Details of such disposal should be judged on a site-specific basis.

It was the opinion of the Committee that such material should not pose a problem in a landfill site to which children would not have access.

9.0 CONCLUSIONS

1. It is prudent to lower children's blood lead levels as much as practically possible.

2. While available evidence is insufficient in a number of areas, the available evidence is sufficient to allow the Committee to provide advice on a reasonable approach for establishing site-specific soil lead guideline levels.

3. The elevated blood lead levels observed in children under the age of six in the vicinity of the secondary lead smelter in South Riverdale are of sufficient concern to warrant remedial environmental action.

4. The observed difference in blood lead levels between the South Riverdale children and the urban "control" children is probably due to environmental lead sources. These environmental sources include air and dustfall lead, soil lead and house dust lead.

5. Children's blood lead levels appear to vary directly with soil lead levels. However, although soil lead levels may be predictive of blood lead levels in a particular community, this cannot be extrapolated to mean that removal of soil lead will necessarily result in a significant reduction in blood lead levels.

6. The reduction of air and dustfall lead levels, soil lead levels and house dust lead levels to urban "background" levels would be likely to result in a lowering of the blood lead levels in children in South Riverdale to urban "background" levels.

7. Soil lead/blood lead relationships are site-specific due to the influence of many variables, such as socio-economic and environmental factors, and insufficient evidence exists for the accurate determination of this relationship in Ontario.

8. The probable environmental lead pathway, influencing blood lead levels in children in South Riverdale, involves air and dustfall lead, soil lead, and house dust lead. Available evidence is insufficient to conclude whether or not blood lead levels would be lowered significantly by remedial action against any one of these lead sources alone.

9. Soil lead removal alone, without thorough lead-contaminated house dust removal, is unlikely to result in a major decrease in mean blood lead levels.

10. Soil lead and house dust lead removal may not result in a significant long-term reduction in blood lead levels unless the air and dustfall lead levels are reduced to appropriate levels.

11. Available evidence indicates that the availability of soil lead, primarily through dust formation, is a critical factor in determining the influence of soil lead on blood lead through the soil lead ⟶ house dust lead ⟶ blood lead pathway. Soil lead that is always covered by sufficient grass appears to be bound and less influential on blood lead.

12. The lack of statistical correlation between the blood lead levels of individual children and their residential soil lead levels, and the available evidence indicating that environmental lead throughout a community plays a role in elevating blood lead levels, indicate that remedial measures should be applied to the community as a whole, not just to residential property.

13. Remedial dust control measures should be undertaken on non-residential lead-contaminated soil that is not directly accessible to children to prevent re-entrainment of the dust lead in the community. Remedial measures may simply involve sodding of open dirt areas, or could involve paving or soil replacement.

14. Based on the World Health Organization's recommended maximum tolerable daily intake for young children, and on current estimates of dust ingestion in young children, the highest dust lead level that would keep the average young child within the maximum tolerable daily lead intake (assuming 50% of the .... maximum tolerable daily intake comes from soil/dust) is 500 ppm. However, this must be interpreted cautiously.

15. The proposed 500 ppm soil lead guideline for growing root and leafy vegetables is appropriate, based on current information. This guideline level cannot be extrapolated to provide a basis for the contribution of soil lead levels, to blood lead levels, through the soil lead ⟶ dust lead ⟶ blood lead pathway.

16. Current information on environmental lead/blood lead interactions in Ontario is severely lacking. If a thorough epidemiological study were to be conducted at the time the remedial action is undertaken, the information gathered would be valuable to the review of environmental lead guidelines and standards in the future.

10.0 RECOMMENDATIONS

It is recommended that:

1. Soil lead guideline levels be established between 500 ppm and 1000 ppm.

   A 500 ppm guideline level is appropriate for agricultural areas.

   A 1000 ppm guideline level is appropriate for areas to which children do not have routine access.

   A guideline level between 500 and 1000 ppm is appropriate for areas to which children do have routine access. Socio-economic and technical factors should be assessed in determining the actual guideline levels for specific sites.

   The Committee representatives from government and industry are of the opinion that available scientific evidence does not support a soil lead guideline level lower than 1000 ppm. However, for sites to which children do have routine access, the representatives from the South Riverdale Community Health Centre, the Niagara Neighbourhood Association, the Ontario Association for Children and Adults with Learning Disabilities and the Toronto Department of Public Health feel that a 500 ppm guideline level is necessary;

2. Soil removal, where conducted, should occur to a depth of 30 cm.

   Excavated soil should be subjected to the leachate extraction procedure set out in Regulation 309

under the Ontario - Environmental Protection Act to determine whether or not it is a hazardous waste. If it is not a hazardous waste, it can be deposited in an approved landfill site. If it is a hazardous waste, then special disposal arrangements will be necessary;

3. Soil removal should be accompanied by thorough dust removal from the community in order to maximize the potential for blood lead reduction. This would involve cleaning the interior of houses and also dusty commercial and industrial areas (e.g., parking lots) in order to avoid re-entrainment of lead-contaminated dust.

   Ideally, soil and dust removal should be accompanied by action to lower air lead and dustfall lead levels so that long-term blood lead reduction may be realized;

4. Protocols for soil removal and dust removal should be established and assessed prior to the initiation of remedial action;

5. A rigorous epidemiological survey should be conducted in conjunction with the clean-up efforts. Protocols for such a study should be thoroughly assessed and evaluated prior to its initiation.

   The information gained from such a study will be valuable for future reviews of environmental lead standards and guidelines;

6. The Ministry of the Environment undertake a review of all environmental lead standards, guidelines and criteria in the light of recent medical evidence on the potentially adverse affects of lead at very low blood lead levels.

   In addition, it is recommended that a dustfall standard for lead be established, if feasible; and

7. Although the Royal Society of Canada Lead Report recommends that soil replacement be undertaken only where blood lead surveys indicate that the geometric mean blood lead level of the children studied is significantly elevated (i.e. $\geq$ 3 ug/dl) above background, the Committee recommends that in communities such as the Niagara Neighbourhood where too few children may reside to allow a statistically significant blood lead survey, remedial action should be taken if the soil lead levels exceed the guideline level.

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12.0 APPENDICES

12.1 MOE "Upper Limit of Normal"* Guideline for Lead in Soil

MOE "upper limit of normal"* contaminant guidelines for non- agricultural surface soil represent the expected maximum concentrations of contaminants in surface soil in areas of Ontario not subject to the influence of point-source emissions.

These guidelines were calculated by taking the arithmetic mean of available data and adding three standard deviations of the mean. For areas not significantly affected by point-source emissions, it would be expected that 99% of samples analysed would show contaminant concentration below the "upper limit of normal" guideline level for that contaminant.

The "upper limit of normal" guideline for lead in soil from urban areas (i.e. greater than 10,000 population) of Ontario is 500 ppm. For rural areas of Ontario, the "upper limit of normal" guideline for lead in soil is 150 ppm (MOE, 1986 (b)).

For Toronto, the mean plus 3 standard deviations of data assimilated by the Phytotoxicology Section of the MOE for lead in soil, is 550 ppm.

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* The term "normal" is used here as a description of the mathematical distribution of the results of soil analyses. The use of "normal" in this context does not imply that the values are or are not environmentally acceptable nor that they are or are not the result of natural occurrences of the contaminant.

For South Riverdale, soil data collected from sites outside the area designated by the Toronto Department of Public Health as being a risk to children, indicate that the mean soil lead concentration is 419 ppm and a corresponding "mean plus three standard deviations" lead concentration for this area would be 1060 ppm (Rinne, 1986(d)).

In a "control area" of Toronto, bounded by Queen Street, Gerrard Street, the Don Valley Parkway and the CNR corridor (approximately 1500 m upwind of the Canada Metal Company), soil sampling data collected in 1985 revealed a mean lead level of 315 ppm, with a standard deviation of 162 ppm, for a mean plus three standard deviations concentration of 800 ppm (Rinne, 1986 (d)).

Surveys of soil lead concentrations in the immediate vicinity of major roadways in Toronto are difficult to compare with other MOE soil lead surveys, as the sampling procedures often differed, however, the MOE Phytotoxicology Section has assessed available data and concluded that "lead concentrations in the top 5 cm of soil may commonly exceed 500 ppm near major roadways and busy intersections" (Rinne, 1986 (d)).

Available MOE soil lead data indicate that "lead concentrations in surface soil (0-5 cm depth) above 1000 ppm are rarely encountered in Ontario except in the vicinity of secondary lead smelters" (Rinne, 1986 (d)).

12.2 Committee Membership

Dr. Edward Ellis
Toronto Department of Public Health

Dr. John Horn
Outerbridge, Horn Ltd.
Consultant to Canada Metal Co. Ltd.
Toronto Refiners and Smelters Ltd.
and Tonolli Canada Ltd.

Mr. Goff Jenkins (Secretary)
Hazardous Contaminants
Coordination Branch
Ontario Ministry of Environment

Dr. Sam Linzon
Phytotoxicology Section
Ontario Ministry of Environment

Ms Maureen McDonnell
South Riverdale Community
Health Centre

Ms Barbara McElgunn
Ontario Asociation for
Children and Adults with
Learning Disabilities

Dr. Jean M. O'Heany
Special Studies and Services Branch
Ontario Ministry of Labour

Ms Elizabeth Quance
Niagara Neighbourhood
Association

Dr. Michael Rachlis
Consultant to South Riverdale
Community Health Centre

Mr. Rob Rinne
Phytotoxicology Section
Ontario Ministry of Environment

Mr. Barney Singh
Central Region
Ontario Ministry of Environment

Dr. Jackie Sitwell
Environmental Health Directorate
Health and Welfare Canada

Dr. Lesbia F. Smith
Public Health Branch
Ontario Ministry of Health

Ms Beverley Thorpe (Chairman)
Hazardous Contaminants Coordination Branch
Ontario Ministry of Environment

Dr. Barbara Wallace
Consultant to Niagara Neighbourhood Association

Observers:

Mr. P. Irwin, President
Canada Metal Co. Ltd.

Mr. Ira Kaufman
Toronto Refiners and Smelters Ltd.

Mr. Frank Kovacs
Sherway Ratepayers Association, Mississauga

Mr. Sergio Legatti
Vice-President, Manufacturing
Tonolli Canada Ltd.

12.3 Terms of Reference

Purpose:

To recommend a scientifically defensible soil removal guideline for lead-contaminated soil based on the available scientific information.

Approach:

1. Assess the correlation between soil-lead levels and blood-lead levels.

2. Assess the correlation between lead in dust-fall and blood-lead levels.

3. Assess contribution of routes of lead exposure to blood-lead levels.

4. Recommend a defensible soil-removal guideline for lead-contaminated soil.

12.4 Work Plan

Meeting 1 - January 7, 1987

1. Finalize Terms of Reference

2. Identify Resource Information

3. Establish Work Plan

4. Assign Tasks

Meeting 2 - February 23, 1987

1. Review draft report of scientific assessment prepared by Ministry of the Environment staff.

2. Identify major omissions and areas of disagreement.

Meeting 3 - March 9, 1987

1. Review second draft of report.

2. Identify conclusions and recommendations.

Meeting 4 - April 13 and 15, 1987

1. Review complete draft report and the recommendations to Minister of the Environment.

2. Prepare final report. Distributed May 4, 1987.

Final Comments

1. Committee members submitted editorial comments and dissenting opinions which were received up to May 19, 1987.

2. Amended report submitted to the Minister May 22, 1987.

12.5 City Council Letter

As indicated in Section 8.0, Toronto City Council, in a letter dated March 31, 1987, made eleven requests of the Minister of the Environment in regard to the replacement of soil in South Riverdale. The Committee did not address these requested actions specifically.

The City Council letter is appended on the next two pages.

COPY

CITY OF TORONTO

Department of the City Clerk

City Hall, Toronto, Ontario, Canada M5H 2N2

Roy V. Henderson / City Clerk

Barbara Caplan / Deputy City Clerk

cc: Dr. A. S. Macpherson
Medical Officer of Health

Attention: Mrs. Merle MacDonald 392-7025

March 31, 1987

MINISTRY OF THE ENVIRONMENT

APR 1987

CONTAMINANTS

The Honourable James Bradley
Minister of the Environment
Province of Ontario
135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

Dear Mr. Minister:

At its meeting held on March 23, 1987, City Council had before it the attached Clause 7 of Board of Health Report No. 4 entitled, "Replacement of South Riverdale Residential Soil Containing Elevated Lead".

Council requests you, Mr. Minister:

1. to do additional soil testing as necessary to identify all sites in the designated blood lead testing area which have soil lead exceeding the selected soil lead replacement criteria.

2. to develop an enforceable standard for lead in dustfall such that soil lead will not accumulate over 500 ppm in residential areas.

3. to proceed without further delay with the replacement of some soil in the South Riverdale designated blood lead testing area.

4. to replace residential area soil in the South Riverdale designated blood lead testing area according to option 5 (500 ppm all sites) as a highly desirable program.

5. to change if necessary your draft soil lead guideline for the decommissioning of industrially contaminated sites for residential redevelopment in order that it conform with the South Riverdale soil replacement criteria ultimately approved by the Ministry.

SEE OVER FOR REGISTRATION

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6. to commence soil replacement in 1987, with completion of the entire program no later than 1988.

7. to arrange funding for a temporary full-time, and a half-time, community information officers to help coordinate community involvement, and that the actual employing agency be the South Riverdale Community Health Centre.

8. to plan and budget for final cleaning of all residences where soil is replaced.

9. to review as a matter of urgency the emission control levels that have been established for facilities such as Canada Metal;

10. to work with the City of Toronto in developing an approach to Canada Metal to secure at least a portion of the cost of replacing the soil in the South Riverdale area; and

11. to engage consultants to carry out detailed cost and feasibility studies as soon as possible.

Council also forwards the report (January 30, 1987) from the Medical Officer of Health entitled, "South Riverdale - Ontario Blood Lead Study Comparison" to the Provincial Ministries of the Environment, Labour and Health, for their consideration relative to the issues of replacement of lead contaminated soil, reduction of environmental and industrial sources of lead in the Province and health concerns for the population.

Yours truly,

Ray V. Henderson.

City Clerk

mcm/fm
MM

Encl.

cc: Medical Officer of Health

Commissioner of Public Works

Commissioner of Buildings & Inspections

12.6 Dissenting Opinions

The Lead in Soil Committee was comprised of representatives from diverse fields. Although this report attempted to address and reflect each Committee member's views, it was recognized that certin Committee members may hold dissenting opinions on certain of the conclusions and recommendations expressed in this report.

Accordingly, the Chairman stated that any written dissenting opinions transmitted to the Chairman would be appended to this report. The sole dissenting opinion received is appended in this section.

THE LEAD INDUSTRY COMMENTS ON THE LEAD IN SOIL COMMITTEE REPORT

The three secondary lead smelters represented at the Committee were Canada Metal Co. Ltd. and Toronto Refiners and Smelters Ltd. and Tonolli Canada Ltd. These industries are grateful for the opportunity to put forward their views at the hearing. These industries do not endorse or adopt the Lead Committee Report. In particular these industries do not adopt or accept all of the medical evidence or the scientific reports put forward by the committee in support of the conclusions of this committee. The industries do not agree with or adopt many of the conclusions and recommendations of the committee report.

The lead recycling industry in Canada is essential in the management of scrap lead in general and in scrap automobile or truck batteries in particular. An essential part of the recycling of this product is the handling of the broken battery and the smelting of the recovered lead into lead product that can be reused. The Royal Society of Canada Report titled " Lead in the Canadian Environment: Science and Regulation", published September 1986 at page xxxi states " The secondary lead smelters,...are essential to overall operation of the industry and to environmental clean-up".

Batteries are heavy and bulky and therefore expensive to

transport, making it unlikely that Canadians will ship lead batteries far from urban centers for recycling, so that secondary smelters will likely remain an urban presence. The United States recently classified lead waste as a hazardous product. Specialized dump sites, insurance and handling costs have forced nearly 60% of the USA recycling capacity out of business. The dumping of old batterys in vacant lots and at landfill sites is now a major problem in the United States.

Ontario has recently passed tough new leachate tests that require lead slag to be treated as a hazardous waste for dumping purposes. This is the same action that the United States took and that the Royal Commission feared might cost Canada its recycling industry.(see page 53, Royal Society Report 1986).

The recycling and handling of lead can be hazardous. The secondary lead smelters in Ontario are monitored by the Ministry of the Environment in accordance with the applicable environmental legislation. The industry feels that the strict standards and guidelines, already in effect, are effectively protecting the environment around the plants. The industry does agree with the conclusion of this Committee that there is no scientific basis for recommending a specific soil replacement level at either 500 ppm or 1000 ppm soil lead as contemplated by the committee.

The specific replacement of leaded soil around one or more of these three secondary lead smelters can only be justified if the medical evidence shows some risk of harm at the current blood lead levels in the population presumed to be at risk. This Committe Report has examined at length the blood lead data of the residents living in the area of these secondary lead smelters.

There are no actual cases of overt or clinical lead poisoning to be found among the residents living in the vicinity of these secondary lead smelters. There is no evidence of a statistically significant elevation of the blood leads levels of any of the residents in the area except for one sample of children, aged Ø-6 years that showed an average elevation of approximately 2-3 ug/Dl with an average of 13.9 ug/Dl when compared to their urban cohorts who had a mean blood lead level of 11.9 ug/Dl.

When we examine the potential benefit or maximum expected average reduction in these childrens blood leads to be obtained by setting a soil removal guideline we must remember that the maximum possible reduction of blood lead levels of the children living in the affected area is actually limited to the difference observed between the affected children and their urban cohorts which is 3.Ø ug/Dl for the group of children in

that area. This maximum reduction of blood lead by 3 ug/Dl, is only theoretically possible, if one assumes that the elevated soil lead levels actually accounts for and contributes 100% of the elevated blood lead levels of these children.

This maximum reduction in blood lead of 3 ug/Dl assumes that all of the affected childs additional body lead burden is a direct result of the childs exposure to lead in soil. That is not so. The committee heard evidence from the Toronto Board of Health representative, who stated that there is no correlation between the soil lead levels around an individual childs home and the blood lead level of that child. The Ontario Blood Lead Survey 1984 and the Toronto Board of Health South Riverdale reports showed that soil lead level along with 3 other factors accounted for only approximately 20% of the blood lead level increases observed.

We are forced to conclude that replacement of all of soil in South Riverdale with lead free soil will perhaps reduce the average blood lead of a child 0-6 years in that area by 1 ug/Dl, if at all. Only that small group of children will be affected by this insignificant reduction. No other group will be affected as no other group has a blood lead level significantly different from the blood lead level of the urban control group.

Remedial clean-up action by these industries has already significantly reduced the blood levels of these children in the area of Canada Metal. In 1973 the children in this area had an average blood lead of 28 ug/Dl with 13% of the children at levels over 40 ug/Dl. These blood lead levels have been reduced to the current average of 13.9 ug/Dl with 18% of the children over 20 ug/Dl. It is unlikely that soil replacement will lower these levels further. In fact the recontamination of this area with lead dust during and following removal of leaded soils will ensure that blood levels of the residents of South Riverdale will rise in the short term.

In 1974 The Environmental Hearing Board recommended that soil having a lead content of more than 3,000 ppm be removed from the South Riverdale area and the removal criterion was set at 2,600 ppm to allow for a saftey factor of 400 ppm to account for sample and laboratory analysis errors. The Hearing Board and the Blood Lead Analysis Task Force published extensive reports and reasons in support of the 3,000 ppm soil removal level guideline. The Ministry of the Environment has concluded that continuing emissions from Canada Metal have not been a factor in the recontamination of that soil that was replaced in 1977. In fact soil lead levels in the vicinity of Canada Metal have fallen on the average of 17% since 1977. Heavy construction at the railway yards and the new dome stadium near Toronto Refiners and the dismantling of the old ESB/Prestolite

plant near Tonolli make it difficult to determine what the effect of emission controls has been in these areas because of non-smelter recontamination by dust from these operations.

There is, therefore, in fact a soil lead replacement guideline value that has been applied to the area around Canada Metal and Toronto Refiners and Smelters. The industry can see no defensible reason for the lowering of this 3000 ppm value to some arbitrary value that is lower, particularly when this committee can not scientificaly justify a further reduction to a lower soil lead level guideline. The decision to further reduce the permitted levels of lead in soil by soil replacement simply is not supported by any evidence that the reduction of soil lead levels in these areas will further reduce the childrens' blood lead levels. This particularly in view of the low blood lead levels of the residents that are currently observed at the present levels of lead in the soils in these areas.

The community representatives have argued that the scientific reports presented in the Committee Report under Section 3.2, document some subtle but important reported effects of low level blood leads on human health, and that the evidence of these subtle effects, as reported, justifies the re-examination of the significance of the exposure of the child to lead in its environment. The fact that these reports exist cannot be

questioned. The significance of the results of these reports and the actual results of the reports themselves is very much open to question.

Bornschein et al in ILZRO Topical Reviews on Environmental Health Lead I - Behavioral Effects of Moderate lead Exposure in Children and Animal Models, Internation Lead Zinc Research Organization, Inc., New York (1981) reviewed all 22 studies relevant to the effects of low levels of lead in blood in children available at that time. He concluded that there was no clear trend indicating that moderate lead exposure caused any abnormalities in behavioral development in children; nor was there any compelling evidence which suggested that this was not the case.

Many of the studies reviewed suffered from methodological deficiencies that undermined their credibility. It was concluded that the findings were contradictory and did not offer any resolution to the question of whether or not lead at low levels is a heath hazard as reflected in impaired neurobehavioral development.

In a paper titled Independant Peer Review of Selected Studies Concerning Neurobehavioral Effects of Lead Exposures in Nominally Asymptomatic Children: Official Report -Appendix 12-C of the External Review Draft of the EPA Document Air Quality

Criteria for Lead. p.VI (November 14, 1983), an independent panel of reviewers also concluded that these studies were inconclusive and inconsistent. That report does suggest that socio-economic variables accounted for all of the observed difference in cognitative functions between children exposed to low, medium and high levels of lead exposure.

The Royal Society of Canada Report, published in September of 1986 said at page 223, " Moreover it is hard to detect these effects at the blood lead levels observed in Canadian children. Other effects on children are also hard to demonstrate at such levels. The same is even true of suggested effects on growth and development". The debate about the interplay of lead levels, socio-economic variables, nutrition and nurture still continues inconclusively.

The relevance of these studies to the South Riverdale lead removal question is clearly that the socio-economic factor, and not soil lead exposure at the current levels, is the single most important factor in determining the performance of these children in their growth no matter how defined, and no matter at what age. The fact that the South Riverdaale area and Ontario in general enjoys high socio-economic standards makes it therefore highly unlikely that any adverse health effects no matter how small will ever actually occur in South Riverdale. These adverse health effects, at low blood lead levels, if they

do occur, only occur in socially disadvantaged children.(Royal Society Report, page 204,).

It must be remembered that all urban Toronto children have blood levels above zero and into the ranges of the studies cited in this Committe Report. There is absolutely no evidence to suggest that the children resident around the lead smelters, and living in the so called "high risk area" are any different mentally or physically from any other child in the City of Toronto. Nor are they in any way different from their urban cohorts, anywhere, in any physical or mental way, except for a small increase in blood lead in some of the children. More over, the differences in blood lead levels that have been found between the urban cohorts at 11.9 ug/Dl and the South Riverdale children at 13.9 ug/Dl are so small that the conclusions of no harm are supported by logic and uncontradicted by any other evidence of impaired functions in these children.

Lead in the environment can not affect a child's blood lead level unless the lead is available to the child and the child actually ingests that lead. This Committee has proposed that the actual route of soil lead to the child is through the ingestion of leaded dusts, probably from the child's hands. The recommendations of this committee should then be directed toward measures that will break this chain of availability to ingestion.

The cleaning of parking lots and streets, the soding of open bare areas and the cleaning of house dust may reduce blood lead levels by breaking that chain of ingestion. It is simplistic to assume that the soil lead is the only source of lead to these children. The fact that the blood lead levels of children living in the area is not related to the observed soil lead levels in that child's yard is convincing and logical evidence in support of the conclusion that the blood levels of the children are independent from and not influenced by the soil lead levels in the areas where these children live.

The removal of leaded soils in South Riverdale will generate more lead dust and that dust will be available to the residents in the form of dusts that are geographically widely spread. The replacement of soil will reduce the soil lead levels but will not effect the reduction of blood lead levels that is desired. The industry cannot afford to support a program that is such folly. The public should not be called upon to bear that expense either. Soil replacement as proposed will be a waste of public funds for purely political motives.

The Committee has not only recommended soil replacement. Recommendations 3 & 6 of Chapter 10.0 recommend a review of all applicable guidelines and standards and in particular the necessity for a lead in dust fall standard. A lead in dustfall

standard would be technically unenforceable. Increased regulation and a series of more stringent emmission standards as proposed by Section 10.0 is unacceptable to the industry because it is not necessary.

Blood lead levels in children and adults in Ontario as a whole have been falling at the rate of 0.5 to 1.0 ug/Dl per year since 1976, whether or not the children live near a source of lead. The blood lead levels in children around the Canada Metal smelter have fallen almost 15 ug/Dl on the average since 1973. The lead in soil levels at Canada Metal have fallen 17% since 1977. Lead in dustfall is clearly on the decline in the South Riverdale area. New criteria and more regulations are not simply not required.

The Royal Society Report recommended that the lead industry upgrade more quickly from the old existing plants. The Ministry of the Environment has placed another financial road block to the ability of the secondary lead smelter industry to up grade by defining the slag waste from the furnaces as an hazardous product. Now these industries face the reality of trucking thousands of tons of lead slag all the way from Toronto to Sarnia so that the waste can be dumped at Tricil. This kind of needless financial burden is unnecessary and unfairly increases the operating costs of an industry that is so essential to the preservation of a lead and acid free environmmnt. The proposed

soil replacement and follow up blood lead testing proposed in recommendations of this Soil Committee Report is simply an academic exercise and as such is a waste of money.

What is now required is the responsible use of an estimated 5 to 15 million dollars of public funds that the Ministry may foolishly spend on soil replacement in the South Riverdale community. The responsible recycling of lead should be supported by the Ministry of the Environment and their continued support in stepwise upgrading of the industry plant should continue. The Minister should dedicate a new dry slag dump site for all smelter wastes, near Toronto.

The secondary lead industry can not properly support a project that is really just an academic project of statistics and testing. The actual proposals and recommendations are made without a basis in scientific fact; they will do more harm than good and they are a terrible waste of the taxpayers money. The support of AIDS victims or shelter for the homeless or the displaced teenage person are projects that are more deserving of support than this projected soil replacement and clean-up plan. Truly, some health priority has gone terribly wrong here.

12.7 Statistical Analysis

In order to clarify the interpretation of available soil lead/blood lead epidemiological data, the Committee put forth a number of questions to Dr. David Andrews. Dr. Andrews is Chairman of the Department of Statistics at the University of Toronto, Director of the Clinical Research Support Unit, and Director of Graduate Training, Preventative Medicine and Biostatistics, Faculty of Medicine, University of Toronto. Dr. Andrews is a full professor in the Department of Preventative Medicine and Biostatistics.

The Committee initially drafted five questions for Dr. Andrews' response (page A-10). These questions were then augmented by four questions from Dr. M. Rachlis (page A-11), which resulted in a total of eight questions that were put forth to Dr. Andrews (page A-12).

The response to these questions was received after the final draft of this report was written, and is appended following page A-12.

1. Do the data obtained from the Ontario Blood Survey, the City of Toronto Board of Health's South Riverdale Blood Lead Survey (1984) or the Niagara Neighbourhood Survey, support a causal link between the amount of lead in blood, and
   (a) the amount of lead in soil
   (b) the amount of lead in air
   (c) the amount of lead in house dust.

2. Can the relative contributions to blood lead from lead in soil, air and house dust be estimated?

3. Comment on and compare, the methodologies and data used in these studies. Could you suggest other analyses which would help to better answer questions 1 and 2? Can you suggest any other data which should be included in these analyses?

4. Do the data and analyses from these studies support the establishment of a scientifically defensible level of lead in soil at which the removal of the soil would lower the level of lead in children's blood in South Riverdale by 2-3 ug/decilitre, a clinically significant amount?

5. Do the data and analyses from these studies support the establishment for scientifically defensible level of lead in air at which the reduction to this level would lower the level of lead in children's blood in South Riverdale by 2 ug/decilitre?

13 Langley Avenue
Toronto M4K 1B4
March 11, 1987

Ms. Beverley Thorpe
Supervisor, Hazardous Contaminants Coordination Branch
Seventh floor, 40 St. Clair Avenue West
Toronto M4V 1M2

Dear Ms. Thorpe;

I would like to provide you with some additional questions for Professor David Andrews who is doing some work for Dr. O'Heany.

1. Is the data from the Ontario Blood Lead Survey and the 1984 Toronto Department of Health Riverdale Blood testing program able to assess the causal link between children's blood lead levels and soil lead levels?

a), b) or c)

2. If the answer to question #1, is yes, what is the statistical power to detect such a relationship?

3. The Ontario Blood Lead Survey underestimates the number of industries to which those children were exposed. What is the effect on the blood lead/soil lead correlation of this underestimate?

4. Do the results of Stark (1982) or Angle (1982) regarding the blood lead/soil lead correlation have more or less validity than those from the comparison of the Ontario Blood Lead Survey and the Riverdale 1984 testing program?

Could you please send Professor Andrews copies of Stark's and Angle's papers? Goff has them. Thank you.

Sincerely yours,

Michael M. Rachlis M.D.

1. Angle CR, McIntire MS. (1982) Children, the barometer of environmental lead. Adv Ped. 29:3-31.

2. Stark AD, Quah RF, Meigs JW, DeLouise ER. (1982) The relationship of environmental lead to blood-lead levels in children. Env. Res. 27:372-383.

1. Do the data obtained from the Ontario Blood Survey, the City of Toronto Board of Health's South Riverdale Blood Lead Survey (1984) or the Niagara Neighbourhood Survey, assess or support a causal link between the amount of lead in blood, and

   (a) the amount of lead in soil
   (b) the amount of lead in air
   (c) the amount of lead in house dust.

2. If the answer to question 1a), b) or c) is yes, what is the statistical power to detect such a relationship?

3. Can the relative contributions to blood lead from lead in soil, air and house dust be estimated?

4. Comment on and compare, the methodologies and data used in these studies. Could you suggest other analyses which would help to better answer questions 1, 2 and 3? Can you suggest any other data which should be included in these analyses?

5a) Do the results of the Stark (1982) or Angle (1982) studies regarding the blood lead/soil lead correlation have more or less validity than those from the comparison of the Ontario Blood Lead Survey and the 1984 South Riverdale testing program?

b) In your opinion, which of the above studies would be more applicable to the establishment of a soil removal guideline in Ontario.

6. Do the data and analyses from these studies support the establishment of a scientifically defensible level of lead in soil at which the removal of the soil would lower the level of lead in children's blood in South Riverdale by 2-3 ug/decilitre, a clinically significant amount? If so, what would this level be?

7. Do the data and analyses from these studies support the establishment of a scientifically defensible level of lead in air at which the reduction to this level would lower the level of lead in children's blood in South Riverdale by 2 ug/deciliter? If so, what would this level be?

8. It has been suggested that the estimate, in the Ontario Blood Lead Study, of the number of industries to which children were exposed may be inaccurate. If the O.B.L.S. underestimated the number of industries, what would be the effect of this on the blood lead/soil lead correlation.

DEPARTMENT of STATISTICS
UNIVERSITY of TORONTO
Toronto, Canada M5S 1A1

David F. Andrews, Chairman 416-978-4284 david@utstat

Mr. Robert Kusiak,
Special Studies and Services Branch
Ontario Ministry of Labour
400 University Abenue, 8th Floor,
Toronto, Ontario
M7A 1T7

April 20, 1987

Dear Mr. Kusiak

As you requested, I have reviewed the Toronto Board of Health's South Riverdale Blood Lead Survey (1984) and the Niagara Neighbourhood Survey, and the two published reports of Stark (1982) and Angle (1984). The questions, 1 - 8, raised in your letter of March 13 asked for judgements and opinions on the scientific evidence presented in relation to issues of policy. The focus of your inquiry is on environmental factors. It is important to note however that age and SES (or rather all that it is a surrogate for) are important factors which explain much of the systematic variation in blood lead levels. Stark *et al* choose to study environmental *or* age/race factors. In my opinion it is important to investigate all of the major factors simultaneously in cases where these are related -- as they are here. The Omaha study allows for only a simple dependence on age -- by splitting on the age groups < 5, > 5.

I raise this issue first because the Ontario data, Table 4, suggest that three year olds have elevated levels. Two thirds of the Riverdale sample is three or under.

1. Do the data assess or support a *causal* link between the amount of lead in blood and lead measured in air, dust and soil?

   Observational studies can only support the idea of a causal relationship and sometimes give an estimate of the size of its effect. The Niagara and Riverdale studies were not designed to yield information

on the relation beween blood lead and these environmental factors. A study with this goal would have involved cases subject to much greater variation in these quantities. The Omaha study, by omitting the influential variable SES, has, to some degree inflated the estimates of the effects of the environmental variables with its influence. The New Haven study, by omitting the influential variable, age (and perhaps race) has diluted the apparent significance of the environmental variables.

Regression models are useful for assessing the importance of an explanatory variable. Regression coefficients are not useful for assessing the size of the effect of particular variables. Table 2 of the Omaha study points this out most clearly. The lead in soil, air and house dust are highly related causally and perhaps statistically. The individual contributions of these are not clearly assessed by any of the studies reviewed.

2. What is the statistical power to detect such a relationship?

The data to study this are in the blood levels of children in the years just following the removal of soil in Reverdale. If soil has an effect, the best data would come from a comparison of removed and "control" households. The studies reviewed have very little power to assess individual "causes".

3. Can the relative contributions of soil, air, and dust be estimated?

Regression models can assess the statistical significance of these variables. The individual effects are very poorly estimated by regression coefficients. -- You can't pollute/clean the air without affecting the soil and the dust. You can't change the soil without affecting the dust. The studies reviewed do not provide information on the net effect of the change of level of one factor.

4. What other data or analyses would help?

The real questions are i) is there a problem in Riverdale and ii) is there any effective action which can be taken. The answer to i) lies in the interpretation of Table 4. This interpretation would be aided by a graphical display including standard errors and a good understanding of the hazards of exposure to lead at these levels. I do not have the latter.

One of the contemplated actions suggested by your questions is soil removal. If this is effective, the evidence is in a comparison of lead levels of "treated" and "control" households. The fact that the

removal was done imperfectly is not a reason to avoid this investigation. It may be done better in future, it will never be done right.

Regression methods are convenient tools for identifying potentially influential factors. If I really wanted to assess the effect of soil, I would consider a matched pair analysis in which pairs of children are matched by age, SES, and geography (= gas stations, industries, ...) and then study the difference in (log) blood level *vs.* the difference in soil level. I would do this only if I could not afford the time to do a controlled trial.

If I was contemplating a policy of soil removal *ie* if I can afford to remove some soil, I can do this in a controlled way and gain accurate information on the effect of soil removal.

5. Which study is most applicable for establishing a soil removal guidline?

   All of the studies suggest a relation between blood level and soil. None of the studies indicate how much reduction would result from soil removal from specific areas. It may be that the effect of soil removal is age dependent. If this is the case the basis for a guidline would be enhanced by an investigation of this interaction. The Omaha study (Table 2) suggests this.

   The studies also suggest that SES is a lever which controls blood level to a surprising extent. What is at the other end of this lever? Soap? If the real question is how to reduce blood lead levels, some investigation of the uptake mechanism is advised.

6. Do the studies support a defensible level of lead in the soil for which removal would lead to a specified reduction of blood lead? No.

7. And for air? No.

8. What would be the effect of errors in industry counts? It should be relatively easy to estimate the bias of the Ontario procedure by interviewing a small number of Riverdale residents. Proportional or additive errors would have NO effect on the Ontario study. It would not matter if people reported I, 2I or 10I or 10 I +3. In the Riverdale analysis, dominated by the larger Ontario sample, a tendency to record higher values of the industry variable would leave less of the increase in blood lead to be explained by other variables. Whether this tends to increase or decrease the estimate of the effect of soil depends on the pattern of the bias in a very complex way.